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HOSIERY AND LACE,
By the late W. Felkin, Nottingham.

CARPETS,
By Christopher Dresser, Ph.D.

DYEING AND BLEACHING,
By T. Sims, Mayfield Print Works.

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PREFACE.

THE object of this series is to bring into one focus the leading features and present position of the most important industries of the kingdom, so as to enable the general reader to comprehend the enormous development that has taken place within the last twenty or thirty years. It is evident that the great increase in education throughout the country has tended largely to foster a simultaneous interest in technical knowledge, as evinced by the spread of Art and Science, Schools, Trade Museums, International Exhibitions, &c.; and this fact is borne out by a perusal of the daily papers, in which the prominence given to every improvement in trade or machinery attests the desire of the reading public to know more about these matters. Here, however, the difficulty commences, for the only means of acquiring this information are from handbooks to the various manufactures (which are usually too minute in detail for general instruction), from trade journals and the reports of scientific societies; and to obtain and systematize these scattered details is a labour and a tax upon time and patience

which comparatively few persons care to surmount. In these volumes all these facts are gathered together and presented in as readable a form as is compatible with accuracy and a freedom from superficiality; and though they do not lay claim to being a technical guide to each industry, the names of the contributors are a sufficient guarantee that they are a reliable and standard work of reference. Great stress is laid on the progressive developments of the manufactures, and the various applications to them of the collateral arts and sciences; the history of each is truly given, while present processes and recent inventions are succinctly described.

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BRITISH MANUFACTURING INDUSTRIES.

HOSIERY AND LACE.

By the late WILLIAM FELKIN (Nottingham).

TREATISES which are intended to show how by the activity of ingenious minds very important results in Art and Science have been obtained in furtherance of the happiness of mankind, are calculated to give a wholesome stimulus to the prosecution of similar efforts on the part of others who may peruse them. It may safely be said, that in no department of mechanical invention and construction has more persevering and effective skill been displayed, than in that which forms the subject-matter of this and the following paper. The origin, progress, and present results of the stocking frame, are alike singularly interesting and important. Devised by a clergyman, and first improved by a farmer, about three hundred further changes and adaptations have subsequently been patented. All these, except three or four, were made by men who began life at the forge and work-bench, handling the hammer and file; or as workmen, in the machinery the defects of which they practically felt and learnt to remedy, or to make them more effective, by adding inventions of their own. These multiplied powers of production, issuing

as they did in the wonderful inventions of the machine lace manufacture, have constituted their joint results, the staple trades of Nottingham and Leicester.

Mankind was probably first clothed in dried skins, rudely fashioned to the body and used also for protection to the feet and legs. So soon as the bark and stalks of vegetables and trees were reduced to fibres and twisted into thread, as also the wool of sheep and goats spun into yarn, the plaiting of twigs and rushes into baskets would give the idea of warp and weft for materials of cloth, and hence the possible origin of the weaving loom. All these processes may have been known before the Flood. The loom was employed certainly in the age immediately after Noah, in the manufacture of stuffs made from linen, woollen, silk, and probably cotton materials; from China and Babylonia, progressively throughout Asia to the Mediterranean Sea; and somewhat modified in its operations, it came down to the sixteenth century without any mechanical rival whatever.

The art of hand-knitting was the precursor of making looped fabrics by machinery. It is not known when or where, or by whose dexterous fingers, the plaiting or knitting of yarn into webs was first performed. It is, however, simple and, now that it is common, easily acquired. One thread only is continuously used, and one of two or more straight skewers, called knittin pins, are held in each hand. A first series of f loops is formed on the left-hand pin, into the first l of which the right-hand pin is inserted; then thread is passed round it, and it is drawn through;

loop thus worked into is slipped off upon the web already wrought; and the same movements are repeated from side to side, each one passing through a loop formed in the row of loops next below it. The web can be wrought of any shape or size, and varied in its appearance by looping in different ways, as dictated by the fancy of the worker. It is elastic, closely fitting the skin, may be extended without distortion, returning when taken off to its former state, though if the thread be broken, the line of loops set free may unrove the web. There is no historic mention of this art till the time of Henry IV. It was first named in an Act of Parliament of Henry VII.; and in seven following Acts, knit hose, caps, and also hosiers were mentioned. Henry VIII. wore knitted silk *Spanish* hose; and Elizabeth wore a pair of *English* hand-knitted silk stockings. It soon became a domestic art amongst all classes; and justified, by its useful improvement of leisure time, the wise Queen's cautious non-interference with its progress. It has survived in some of its varied forms, and seems not likely ever to become obsolete.

The time, however, came when the operations of human hands and fingers were to be imitated, not only in their ruder but in their more intricate and delicate operations. To increase the riches of the country, and furnish employment with added comforts to the artisan, was the beneficent operation of a loom producing a tissue that perfectly imitated the hand-knitter's web, of equal quality, and with much greater speed. It had nothing in common with the old weaver's loom; it was

much more complete, and of nicer adjustment of parts, each admirably devised, and fashioned with an accuracy at that time almost unexampled. To attempt this, required a masculine self-command; and to accomplish it, a mechanical genius of the highest order. The person to whom England owes this new and intricate machine, was the Rev. William Lee, M.A. That it was an English, and not, as pretended by some, a French invention, is attested by the frame-work knitters' petition, 1656; Cromwell's charter, 1657; Charles II.'s charter, 1663; by Dr. Howell, 1680; Beckmann, Voltaire, and the French Encyclopædists. There have been varied accounts given of the inventor and his stimulus to invention. Aubrey states him to have been an Oxford student, and probably of Magdalen Hall. Aaron Hill adds to this, that he married an innkeeper's daughter, lost his Fellowship, and fell into deep poverty, and was supported by his wife's earnings from knitting. "Watching her, he contrived a loom to do the work more quickly, thereby benefited the nation and became a wealthy man." Rees' Cyclopædia adopts this account in the main. Now this William Lee was not of any Oxford college, nor was he, as stated by Evelyn, a curate in Sussex, nor yet the William Lee from Sheffield, of Clare Hall, Cambridge, M.A. in 1577. This William Lee was a M.A. of St. John's College, Cambridge, but not a Fellow; and he was not expelled from that or any other colleg there. Dr. Thoroton (History of Notts, dated 1677 says, "At Calverton was born William Lee, M.A. i Cambridge, and heir to a pretty freehold here; wl

seeing a woman knit, invented a loom to knit; in which he or his brother James performed and exercised before Queen Elizabeth; and leaving it to one Aston, his apprentice, went beyond the sea; and was thereby esteemed the author of that ingenious machine, wherewith they now weave silk and other stockings. This Aston added something to his master's invention. He was sometime a miller at Thoroton, nigh which place he was born." This history was published only sixty-seven years after Lee's death. William Lee certainly officiated at Calverton, where the living was then only of the value of 4*l.* a year. His own "freehold" might enable him to meet the cost of his experiments. The Lees were numerous at Calverton and the neighbouring Woodborough, and have continued so ever since; and the people became mostly frame-work knitters. In the Calverton parish register is the following entry: "Buried Joseph Lee, stockinger, the last of the family of stocking-frame inventor Lee in this parish, 17 April, 1755." Stow says, "In 1599 was perfected the art of knitting silk stockings by steel engines by William Lee, M.A. St. John's College, Cambridge. Tradition attributes its origin to disappointed love." Deering says the same in 1751. Anderson gives the like account. Blackner in 1815 repeats it, with the significant addition, that "the object of Lee's affection was employed in instructing pupils in the art of hand-knitting." Henson, in 1831, gives as the cause of Lee's invention, disappointed love; and Ure, in 1833, agrees as to Lee's impelling motive, unrequited love, "teaching that a man of genius is not to be slighted

with impunity"; and as to his invention, "that remains the most remarkable stride in human d covery." Lee never married. Elmore's clever pict is therefore founded on a myth; and the story "Nut-Brown Maids" is a laboured romance.

Lee, having decided to construct the meditated loo depended on the skill of Nottingham workmen wood and iron, which was then proverbial. His fi machine was almost wholly of wood. The expec tion of realizing a large fortune absorbed all otl interests; and at length led to the resignation of duties as clergyman, although in his portrait, now lo but copied in the arms of the London Frame-wo Knitters' Company, he appears in the gown and cap a Master of Arts, pointing to a hose on his stocki frame; while on the other side, a female is showi her empty and therefore useless knitting pins. T original picture was thus inscribed: "In the y 1589, the ingenious William Lee, M.A. of St. Joh College, Cambridge, devised the profitable art stockings (but being despised went to France), yet iron to himself, but to us and to others of good; memory of which this is painted." His brother, Jan Lee, was his best mechanical helper, and his b workman when his frame was completed, and until t close of his life. James, and each of his fello workmen, wore a needle suspended by a silver ch round his neck; a practice continued by the until the time of Queen Anne. The produce of first frame was sold at Nottingham, but with diffic *because of* the prejudice against machine-w

goods. No exact record exists, left by Lee or any one of those around him, of the steps taken in constructing his, to them, surprising machine; but they must have been as related by tradition, and very much as follows:—

It would seem to him impossible by a machine to knit a *round* web; but he saw that he might knit straight lines of loops one upon and after the other, and then join the selvages to make it round. Then came the idea of throwing the continuous thread across long elastic hooks (needles), whose points should be pressed down into a groove to be filed out on the stem of the wire; and thus, after much labour and loss of time, he made the needle used to the present time (Fig. 1). Placing a row of twelve of these firmly and horizontally in a piece of wood (Fig. 1, *i*) eight to an inch, he made by hand first one loop and then others in succession, from side to side each way; thus looping a pair of garters. Besides this frame, there was needed a cross bar presser (Fig. 2, A) of wood, and properly shaped, to press down at one movement, by one hand, all the barbs of the hooks into the grooves; while with the other, to bring forward the loops already made, and pass them over the beards and needle-heads (Fig. 3, S and R). Thus he made row after row until a long web had been produced. One continuous thread was used, in forming a succession of loops, giving sufficient yarn to each loop across the straight line of needles; passing it along the stems of these, by the operation of jacks and sinkers (Fig. 1, *h* and *f*). The jack is a lever working freely on a wire, upon which it is

balanced; and made of wood in Lee's frame (since of iron), one to every needle. They were kept in place by working in a comb, and were held from falling forward by a light spring (Fig. 1, *k*), acting at the tail of each when not in use. There is a slit in the head of each jack, from which the sinker hangs (Fig. 1, *f*), and

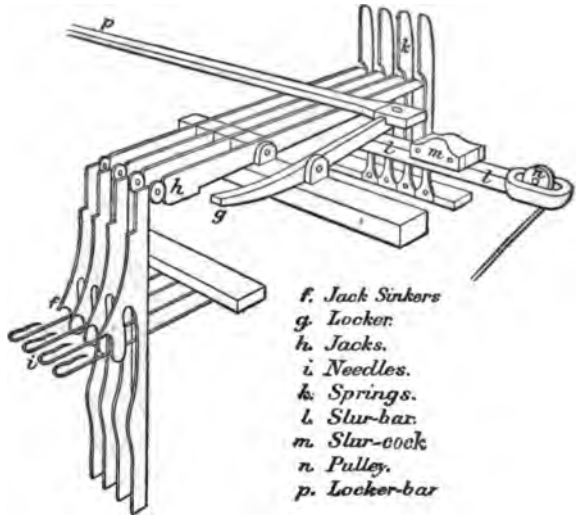
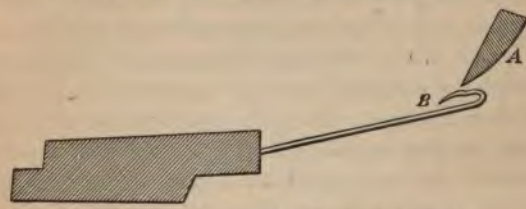


Fig. 1.

acts perpendicularly. The jacks are of thin smooth iron, and so shaped in moulds, as by passing between the needles, to take down the thread for loops, and then to carry them forward under the needle beards, close to their heads. The presser (Fig. 2, A) puts the points of the beards in their grooves (Fig. 2, B); then

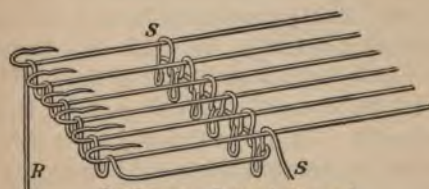
the sinkers bring forward the line of loops already made (Fig. 3, S and R), passing it over the last-formed row; and finally take the web back to the stems of the needles, ready for a new course. The sinker was so



A. Section of Presser-bar to act on B Needle beard.

Fig. 2.

shaped as to perform perfectly five essential operations, and has remained unaltered to the present time. The jacks, following the thread alternately from side to side, are forced down one after the other by an iron



R. Loops of single thread.
S. Loops of web to pass over beards.

Fig. 3.

instrument called a slur-cock (Fig. 1, *m*), which when pulled by treddles (Fig. 1, *n*), strikes the tails up. The machine has to be moved forward by the hand,

then to sink by a central spring, and go back to its first position; the sinkers meanwhile performing their successive duties. Eleven movements are required to form each row of loops, necessitating careful yet rapid use of the workman's hands, feet, and eyes. Three years were spent by Lee in the perfecting of his frame. At length, this indefatigable clergyman and mechanician became the successful inventor and constructor of the knitting machine. He soon saw that by removing loops on the outside selvages to the next needles inwards, the web could be narrowed, and by the reverse process widened, thus shaping it to the leg. The formation of stocking heels required much thought and skill before the difficulty was overcome. By skilful hand-knitting 100 loops may be formed in a minute. Lee made on his first frame 600, and on his second 1200 in a minute, the latter being of double fineness and of silk. Modern narrow hand-frames have from 150 to 600 needles; wide hand ones sometimes 1500 in each row. Thirty courses may be made in a minute; thus producing, according to width and gauge, from 5000 to 40,000 loops in that space of time. The eyes are tried, but the varied muscular exercise is favourable to health. Though at first sight the movements of the machine seem intricate, yet they are not really so, and tens of thousands of lads at twelve and girls at fourteen years of age have begun their life-long labour in them.

Lee formed large expectations of the benefits which this invention would confer on his countrymen, and removed his frame to London, attended by James Lee and other workmen, his relatives, in hope of obtaining

the approving patronage of his sovereign. When the fact of a complicated knitting machine became known at Court, it was thought to be almost a miraculous event. Elizabeth's kinsman Hunsdon requested her inspection of it, and accompanied her to the lodgings of the inventor in Bunhill Row. She expressed her approval of its ingenious construction, but disappointment that the product was a coarse worsted stocking (it was only eight loops to an inch in width), instead of the fine silk hose she had expected. Lord Hunsdon still felt the importance of the invention, and pressed for a patent giving Lee a monopoly of its use. This the queen finally refused, on the ground that "the exclusive privilege of making stockings for all her subjects was too important to be granted to any individual." Her relative, nevertheless, bound his son to Lee to learn the art of frame-work knitting, securing an interest in the expected profit; and thus Sir William Carey became one of the first stocking-maker's apprentices; his father, as it seems, furnishing money for constructing the next and probably some other frames. Lee proceeded to fulfil the queen's suggestion, by constructing a frame of twenty needles to the inch instead of eight, and on which silk hose were made in 1598. This required all the inside work to be reduced to two-fifths thickness of the instruments used in the first. Elizabeth praised and accepted a pair of silk hose from it, but awarded Lee no further encouragement. He was seen at Court no more, but employed himself in his workshop, in the construction of nine machines of still finer gauges. Five years later, he *saw his sovereign* laid in Westminster Abbey. Her

coldness was a severe disappointment to Lee; yet she in reality indirectly pointed out that the inventor's profit lay among the higher classes, and not in a competition with hand-knitters, the cost of whose articles was the money spent in the yarn which they used; whereas hand-knitted silk hose could only be obtained from Spain, and at an excessive price. Not receiving any patronage from James, his secretary Cecil, or the Court, Lee became greatly discouraged, until Sully, Henry IV.'s envoy from France to the English sovereign, desiring to encourage manufactures there, offered to transfer him and his invention to that country. After some hesitation from dread of religious persecution, he consented; and taking James Lee, eight workmen, and as many frames to Rouen, "wrought there with great applause." He himself was presented by Sully to his master and graciously received. He was again brought into note by his success at Rouen, though while waiting at Paris for the grant of a special privilege, his hopes were overthrown, through the assassination of Henry by Ravaillac. Sully retired in haste from the capital; and Mary de Medici withdrew protection from Lee, who, as a Protestant, was in danger and distress. Labouring under a deeply-wounded spirit, he summoned his brother to come and comfort him; but it was too late. When James Lee arrived, he was dead (probably heart-broken), and already buried—where is entirely unknown. This event took place in 1610. After twenty-five years of deferred hope did this great inventor, almost an outcast from his own country and an alien in France, thus succumb

to his adverse fate. England had the honour to give him birth and education; France gave him its brief royal patronage and a grave. No monument has been erected to the memory of Lee, but the foundations were laid by him of a manufacture which has grown into magnificent proportions, and is making rich the entire district where it arose. Thereby his fame is eloquently though silently made known.

On his brother's death, James Lee, with six of the workmen and seven machines, returned to England; two workmen, however, chose to remain at Rouen, with one machine, hoping to get Lee's privilege. The machinery brought back to London was set up in Old Street Square, and became the origin of the hosiery manufacture in the metropolis. The machines were sought after, and sold; while others, on an improved plan devised by Aston, were constructed. These (Fig. 4) had a fixed sinker placed between every two movable jack sinkers, and also twice

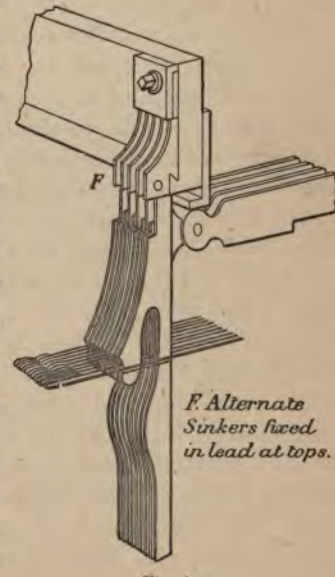


Fig. 4.

the number of needles, so that the gauge and value of the frame itself were doubled. Of these many were soon made in London and Nottinghamshire, and the Venetian ambassador, about 1620, gave 500*l.* for a frame, which, with an apprentice, he sent to Venice. But though in repute for mechanical skill, the smiths there could not give it needful repairs, so that it was brought back to England, and the project failed. Of the workmen left at Rouen, one soon died; the other worked on his unimproved frame for forty years.

Early in the seventeenth century the London Framework Knitters' Company was formed, for regulating wages and opposing non-apprenticed hands. Thus many masters were driven abroad for a time. In 1640 there were two master hosiers in Nottingham, who purchased country machine-made goods. The manufacture spread through the counties of Leicester and Derby, using materials of cotton, worsted, and silk. A frame was taken to Hinckley in 1640; in 1790 there were 1000 in that place, and in 1844, 1750, on which 5*s.* 3*d.* only was earned in a week by making coarse hose. The demand has since then increased greatly, and wages in still greater proportion. The first frame worked at Leicester was in 1670. Much prejudice existed against machine-wrought hose; yet in 1700 the making of worsted hose there had become a trade. In 1750, 1800 frames were employed by many hosiers in that town, who added linen thread hose to their worsted productions.

Returning to the London Company and the power which the members of that body sought to exercise, a

stocking maker (one Pickard) set them at defiance, whereupon they applied to Cromwell the Protector for a charter, alleging that "Pickard taught his art to anyone for money; made underfashioned and unsound hose; and of slightly-twisted yarns." The Charter of Incorporation was granted in 1657, empowering the Company "to make laws consistent with the custom of London, of which city they might choose any citizen as a member; might levy fines by distress, and search for and prove any frame-work knitted goods; and if found ill-made or of deceitful stuff, cut them in pieces." It ordered also that no frames should be exported. Every stocking maker must enter the Company, or pay 5*l.* weekly until he did so, and the statute of Elizabeth as to apprentices was enforced. This was followed by a second charter, granted by Charles II. in 1660, giving power to rule and manage the manufacture of hosiery throughout the kingdom. In 1686 another grant by the Crown extended these and further powers to Ireland, where many frames were at work. More than 400 frames having been exported, a fine was levied on the removal of one without notice, and all were numbered. This stopped the practice. In 1695 there were 1500 frames in and near London. The construction of the general body of machines in this trade at the close of the seventeenth century showed that the frame-smiths had attained great skill. Many of them were at work in fair condition within the recollection of persons still living. Worsted hose were made early in the eighteenth century of three, four, and five-thread yarn, and well-fashioned silk hose were much worn in fancy

colours, and with long ankle-clocks embroidered with the needle on the insteps. Workmen in plain goods earned 3*s.* a day—in embroidered 4*s.*, working usually four days a week in the country, and earning 10*s.*, and in London 15*s.* on an average. Meat was then 1½*d.* a lb., and bread 14*d.* a stone. In 1727 there were 2500 frames in and round London, and 5500 in the provinces. But many of them were unemployed, and the workmen's privations were mainly due to two or more apprentices being taken to one journeyman, a practice which was greatly promoted by parishes offering 5*l.* for each youth taken off their hands. Thus a man at Nottingham had always on an average twenty-five apprentices, and never employed one journeyman for thirty years. Cartwright, who had twenty-three, and Fellows who had forty-nine apprentices, removed their frames from London to Nottingham, 1710, in consequence of frame-breaking having for the first time taken place in London in the shop of one Nicholson. The London Company fined Cartwright 150*l.* and Fellows 400*l.*, and on their refusing to pay, their machinery was sold; but the legality of the proceedings being disputed, the authority of the Company was overthrown by a Committee of the House of Commons in 1753, as tending to a monopoly hurtful to trade, and thus this body ceased to interfere beyond twenty miles round London. Through all these disputes the masters opposed and the journeymen supported the Company. This corporate body became so impoverished by its luxurious extravagance, as to borrow even 50*l.* on security of its pictures and plate.

In 1730 the first stockings of cotton yarn were made. They were of four and five threads, spun in India. This yarn was harsh and unyielding in work; but as the use of cotton hose increased, its quality was improved. Marks were put in the tops of hose to indicate the number of threads used in them; but in spite of an Act of Parliament, they have ever since been falsified. South American cotton wool produces the most pliable yarn. The spinning for hosiery purposes is a difficult operation, but is carried on very largely and successfully at Cromford, Belper, Staleybridge, and Ashton-under-Lyne. In 1750, everything tended to bring the hosiery manufacture into the Midland counties, and accordingly 1600 frames had been sent from the London district thither. At that time there were in the United Kingdom 14,000 frames. The letting out of frames on hire, by owners of them not in the trade, was now for the first time distinctly practised, though resisted by the workmen, as introducing needless frames, and thus overloading the business with machines and hands. Direful effects have ever since resulted from it. Another pernicious practice was imported into the apprentice system. After a few months allowed in which to learn to work the machine, each had a stint of labour set him to perform, and all he earned beyond was his own. This was just to his master and a stimulus to himself. But he has been permitted to do the stint when he pleased during the week; and thus by misusing his leisure hours he has too often become "the Shacking Stockinger."

About the year 1750 hosiery wages were very low; the masters' dwellings were ill furnished and desolate, while the workmen and apprentices were reduced almost to starvation. The quality of their work was deteriorated, and French silk hose were so much in demand that Parliament in 1754 prohibited their importation. For twenty years English hose had Paris put into the welts to induce sales. National rivalry being at length aroused, a contest took place between two selected workmen and their frames, but even the London referees decided in favour of the French. Spanish embroidered silk and mitts were, nevertheless, imitated with success; and some journeymen could earn 12*s.* a day by making them.

Very soon the spirit of emulation and enterprise rose into activity throughout the midland counties, and with marvellous results. No attempt appears to have been made until about 1740 to add machinery to the stocking-frame, so as to vary the texture or face of the web; but in that year a "sliding tuck-presser" was applied. This was so notched on its edge as to allow any of the loops to remain on particular needles, until, by using the ordinary presser, the whole of the loops across the frame were passed over the heads of all the needles upon the web already made. If coloured threads were used, a further variegated face was given to the web. This instrument has since been used for other purposes. Hose, knitted by hand so as to be ribbed in straight lines down the entire length, by reversing the loops in them, were, from their closely fitting the leg, much worn. To produce this ribbing

effect on the stocking frame was, for a time, an object of unsuccessful effort; amongst others, by two framework knitters named Bowman and Roper. Woollett, a hosier at Derby, also brought this question under the notice of his brother-in-law, Jedediah Strutt, who, though an agriculturist, had early occupied himself in mechanical pursuits; and the reference proved successful by the invention of the "Derby ribbing machinery."

In this the principle was introduced of operating upon any one or more of the loops or meshes of a web, by the addition of an independent selecting apparatus (see Fig. 5). This lies at the bottom of all subsequent methods for altering the course of threads at work in hosiery and lace machinery, and consequently the face of the webs and texture of patterns introduced into them. The invention has given to Strutt just prominence among men of talent of that age; though, from its simplicity and easy application in the first instance to the stocking-frame, it but slowly obtained the attention that it deserved in regard to other machines. Strutt was born at Blackwell, Derbyshire, in 1729, where his father was an occupier of land. He was the second son, and received an ordinary education in the neighbourhood. Possessing much decision of character, and an insatiable desire for useful knowledge, of which he early acquired the elements, he became a self-taught practical man, and a skilful mechanician. Having married a sister of Mr. Woollett, a union that proved a very happy one, Strutt removed to Derby, exchanging agriculture for hosiery

manufacture, and thus necessarily became acquainted with the movements of the stocking loom, the most intricate then known. Strutt's invention did not require any alteration of Lee's frame, for it was simply an addition to it. If worked without that addition, it produced a perfect looped plain web, and by placing the added apparatus so as to work in co-operation with it, a ribbed web was the result. It is of iron, and hung on jointed arms in front of the frame; and needles like those in the ordinary stocking frame are placed perpendicularly in this, so as to enter between the

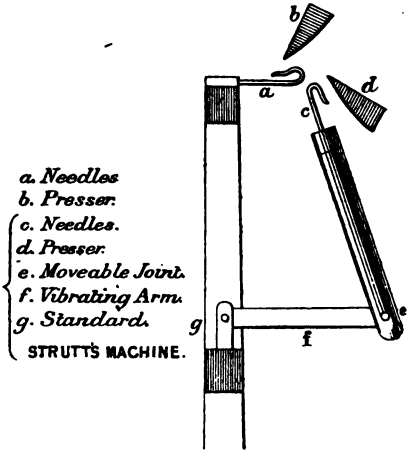


Fig. 5.

horizontal ones of Lee's machine (Fig. 5, *a*, *c* *b* *d*). The number of needles in the added apparatus, and *their relative* places on its extra bar, correspond with

the widths and places of the ribs and number of reversed loops to form them. When all the old frame needles have had their loops pressed, which all face one way, the needles of the new machine are brought by its swinging motion to enter between the old ones, penetrating only those loops which are to form the ribs; and these passing under their beards are reversed, and then pressed again, passing over the needle heads with the other loops, but with the visible parts of the ribbing loops turned the other way. The ribs may be varied in width from one and one, i. e. every other loop, as in sock tops, to any number required by the wearers. Woollett and Strutt took out patents in 1758–9, and their business increased rapidly in these so-called "Derby" ribs. Infringements soon occurred, and actions were brought with success against associations of hosiers, and the patent rights secured. The family retired finally from the hosiery manufacture about 1805, in favour of Paget and Byng. But the demand for ribbed goods of various kinds, and for male and female wear, has enormously increased, while Strutt's principle of selection remains untouched, though its subordination to automatic action has enlarged its productive powers to an extraordinary extent.

Strutt had become connected with Arkwright in 1771, furnishing capital for his cotton-spinning plans, and also skill in overcoming difficulties in their execution. Success was evidenced by the Cromford Mills; and after their partnership expired, by Strutt's erection of four splendid mills at Belper. He, with his then partner, Need, began to weave calicoes at Derby, using

highly-twisted cotton warps; which, though not without much opposition, resulted in the general adoption of the plan. Mr. Strutt died at Derby in 1797, aged sixty-eight. To promote the welfare of his family, to encourage the trades of which he was the founder, and to fill with honour the position to which his talents and integrity had raised him, were the objects he aimed at and attained. His sons, who carried on the business with much success, were also distinguished for literary taste and public spirit. His grandson is the present Lord Belper. What a contrast between the heavy disappointment, sad exile, and lonely death of William Lee, and the bright, useful days of Jedediah Strutt, his long and successful career, followed in only the third generation by a peerage! Modern titles have not always been so well bestowed.

Strutt's apparatus being prominently placed in the front of the stocking frame, would show, to every looker on, the fact of external individual action on the needles, which might otherwise escape notice. But when great numbers were spread over the Midland district, the mechanical selection was seen at a glance, and further developments of such a fertile idea soon began to appear. It lies at the foundation of Morris's patents, 1764 and 1781, for making eyelet-hole ankles and insteps in ladies' hose; also of Crane's patent, 1769, for looped nets; and Else made his machine in 1770, by added operations on the needles. This principle of control and selection, variously modified and applied, produced in succession the knotted, twilled, stump, mesh, and point-net machines.

In the warp frame, where no weft thread is used, but each warp thread loops sideways on its neighbour, every needle, in its wide horizontal range, can be similarly selected and governed in its action. Thus, not only did fancy hosiery modifications cause a large and growing increase of production, but all the machine-wrought plain and fancy lace manufacturers of England and the Continent owe their rise, and much of their extension and value, to the example set in the added mechanism of Strutt. Morris, Crane, and Else, each infringed on him; but as they were employed on other kinds of goods, and did him no injury, no legal proceedings were taken. One Butterfield, about 1752, devised a plan, and Betts constructed it (showing it to Shaw, who with Morris patented it), in which the tuck presser and the ribbing apparatus were combined. The tuck presser brought the loops to be shifted to the needle heads; and in order to make eyelet-holes, these were removed by short, flat-pointed ticklers, fastened to a bar. These ticklers covered the beards, pressed them into the grooves, and then took off the loops; and by a side movement placed each of them on the next needle on either side, leaving a series of fast holes below the next course of loops. This class of machines has passed into every country where hosiery frames are employed.

Harvey, about 1770, brought the *pin* machine from London to Nottingham. This had one crank-pin to every needle. Its further construction is unknown. An improvement on it is used at Lyons and Vienna for making silk nets.

Morris took out another patent in 1781, for passing each of the sinker loops two needles on either side, making a round mesh, and thereby producing what was long known as POINT NET. This constituted an advance in looping machinery, equal to any effected between 1760 and 1800, and from this epoch machine-wrought hosiery and lace diverge into separate trades. Some infringers on Morris used hooks instead of points, while others placed the points differently. In Morris *v.* Branson, 1778, Lord Mansfield held, that "to effect by machinery, in any mode, the working of a whole course of loops at once, which before the patent had been only done loop by loop by hand, was an infringement of it." The jury gave 500*l.* damages.

Modifications of the stocking frame were now vigorously carried on. Else and Hammond laid aside the tuck presser; operating on the loops by ticklers alone, so as to remove them by a sliding needle bar and a side motion. In 1769, R. Frost produced a figured net, by using on the stocking loom a hollow roller, with curved points on the surface, pushing forward the required tickler slides, so as to act, while leaving the others at rest. There being a tickler to each needle, any stitch could be removed and a pattern in lace produced. This was the first plan of self-acting selection resulting at last in the Jacquard machine.

Ross produced in 1767 a velvet pile web, by cutting rows of slack loops. He paid his workmen at the rate of a shilling an hour and retired with a fortune.

Crane patented, in 1769, a method of producing beautiful brocades and flowers, employing a cylinder

roller and draw boy in selecting the needles; but notwithstanding his great mechanical skill, he died a poor man.

Broadhurst reversed Frost's plan, by placing the cylinder in front of the frame, on which iron pins were driven; these acted by spring ticklers on needle eyes, from which stitches were removed without touching the needles, thus producing the required pattern.

Patents were taken out by Horton in 1771 and 1776 for knotted hosiery and double-looped work, most excellent and durable articles, largely used for more than half a century; indeed, in 1795 one thousand frames scarcely supplied the demand. The colleague of Napoleon I., Consul Lebrun, constructed one of these frames for making *fine* knotted hose, at his manufactory in France. Horton had become well acquainted with the mechanism of the stocking frame in his youth, and one day, seeing a workman making on his machine a tuck stitch diamond in the hand of a glove, he proceeded to make stockings of wholly knotted work, using Lindsey's tickler frame on Else's plan with adjustments of his own. A gentleman named March furnished the money to patent the plan and improve upon it; in the latter, he was assisted by Peet, Betts, and Stevenson—clever workmen in the trade. Horton himself was an indefatigable mechanician; and living to an advanced age, realized a large fortune.

In 1776, Brockley, a poor Nottingham stockinger, devised an imitation of Horton's knotted hosiery. The goods were called twilled, and as they were non-elastic, soon went out of use. But he effected an important

alteration in the web, which was made with a silk face outwards, by carrying a cotton thread behind, thus making it a double-looped fabric, known as *platted* work; and so long as the back was of twisted *two* threads cotton yarn, the articles wore well; but when *single* yarn (that curse of the stocking trade) became generally used, their unsoundness caused the manufacture of platted goods soon to become extinct. Meantime these machines had given employment to many hands, and fortunes to their employers, yet Brockley died at Nottingham in very humble circumstances.

Robert Ash, another ingenious but ill-requited mechanic, patented, in 1781, a plan for making "fastened platted work." This was a machine producing an elastic twilled fabric, but the movements were so complex as to prevent its extensive use, although possessing suggestive merits, which did much credit to Ash as a mechanician.

Hague patented, in 1790, an improvement on Ash by placing stumps cast into leads, operating over and parallel to each needle, and this without a presser. This produced a platted web; and the frame was known as the *mesh* machine. Hague was able, but improvident, and sold his invention. He had been fairly educated; his first trade was that of a baker, though afterwards he became a schoolmaster and could solve problems algebraically. He had a poetic vein, even in his cups, singing songs of his own composition in the streets for money. Yet he was well known, and often consulted as a great mechanic. He died at Nottingham

in deep poverty. The goods, made upon about 300 of these frames, were called *elastics*, and when properly made would wear well; but to meet competition they were at length fraudulently turned out, and their manufacture was destroyed.

In 1784, Webbe, of Birmingham, patented a simplification of the Derby ribbing frame; and 300 of these machines were worked for some years at Banff with great profit. Soon after, Rhambolt took the plan to Paris, where, and at other places in France, many machines were constructed upon it.

Articles closely fitting to the body, as vests and drawers, are found conducive to the health of the wearer, whether made of fleecy animal wool, for warmth; of cotton, for economy; or of silk, for its electric properties. Bandaging of electric hosiery web has been long used for surgical purposes. In 1788, Holland, a London hosier, obtained a patent for the manufacture of fleecy hosiery, specially useful on account of its warmth, elasticity, and power of absorption, in many chronic complaints. Patents for improvements were taken out in 1790 and 1792, and his house long retained a well-earned celebrity amongst medical men and the public at large.

No further important hosiery inventions occurred prior to the year 1800.

Notwithstanding the many modifications of the hosiery frame, wages remained very moderate, and profits were only partially and slowly increased by them. A Midland Stocking Makers' Mutual Protection Society had been formed in 1777, having for its object

the prevention of the undue influx of apprenticed boys and girls, which still continued. This society soon became powerful enough to return Mr. Abel Smith as Member of the House of Commons for Nottingham, on which occasion his chair was ornamented with the newly-invented white silk lace. In 1778 a petition was presented to that House from the frame-work knitters throughout the kingdom, stating that they could not by their utmost endeavours obtain the common necessaries of life, by reason of low wages, frame rent, and other charges; but the request for an Act to regulate and settle wages was refused by 52 against 27. The silk hosiers soon after sought to further reduce wages, and this induced people to subscribe money to resist them. Mr. Robert Smith (Lord Carington) said, "The bill again proposed was moistened by the tears of the distressed frame-work knitters." It was thrown out on the third reading by 57 to 18. This was the signal for riots at Nottingham: 300 of Need's frames were broken, houses were sacked, the Riot Act was read, and military called out before quiet was restored. The hosiers opposed all interference, whether by Parliament or the chartered London Company, as tending to drive the manufacture to France, and it was no wonder that there were further riots in the next few years.

About 1782, Elizabeth Drake was the first female employed in chevening hose at Nottingham, i. e. embroidering them by needlework with silk or glazed linen thread. But before fifty years had elapsed, most of the ornamental styles, which had employed many

hands with profit to the hosiers, had gone out of fashion.

Trade revived somewhat at the close of the war with the American colonies, and hosiery wages improved. Hands employed on plain cotton and worsted hose earned 10*s.* to 12*s.*; silk, 10*s.* to 14*s.*; on knotted, twilled, and elastic goods, 18*s.* to 30*s.* a week. Hose made with fancy clocks were paid for one-third above plain prices. At this period there were 17,350 stocking frames in the midland counties, 500 in London, 200 in Surrey, 650 at Tewkesbury, 300 in Northamptonshire, 700 in Dublin, 300 in Cork, and some in Scotland; about 20,000 in all. But by the end of the eighteenth century most kinds of fancy hosiery had gone out of fashion, and 3000 frames went on to plain hose, in addition to a great number of new ones, constructed merely for the rent paid for their use. In 1812 the number of frames had risen to 9285 in Nottinghamshire; Leicestershire, 11,233; Derbyshire, 4700; elsewhere in England, 1921; Scotland, 1440; Ireland, 774: total, 29,632; on the Continent, 13,189.

The demand which arose in the early years of the present century for frame-work knitted hose, pantaloons, and gloves for our army, relieved the trade, but far from effectually; and the country had been sorely visited by several bad harvests. The request for hosiery rapidly declined, so that by the year 1810 the cry, never to be forgotten by any who heard it in those days of dreadful suffering, "Give us work at any price —half a loaf is better than no bread," was uttered by thousands of half-famished frame-work knitters. The

distress in 1811 was beyond patient endurance, and the practice of frame breaking was once more resorted to. In 1710 frames had been broken in London, and in 1723 weaving looms in the West of England. Again, in 1770, silk looms having been destroyed in Spitalfields, some workmen were hanged at their own doors for the offence. In 1773 and 1780 similar lawless proceedings took place at Leicester. The impelling motive for recurrence in 1811 to this wrongdoing was the misery into which the stocking weavers and their families had fallen, nearly half the population of Nottingham, Derby, and Leicester being relieved from the poor's-rate, and many persons sweeping the streets of those towns for scanty aid. In face of the large military force immediately at hand, 1000 frames were within that year broken in and around Nottingham. Food was demanded, and farmhouses were pillaged in the country. Those who directed the outbreak were never known, although 200*l.* reward was offered. Of the actors in it, eight were executed and several transported. This severity, and a temporary advance in the rate of wages, brought this fearful state of things to an end. But for the next forty years the workpeople in this manufacture never emerged from distress; their clear earnings by long hours of labour did not through that interval exceed an average of 7*s.* a week.

A bill passed the Commons in 1812 for the relief of the stockingers, by enacting various regulations bearing on the details of materials, wages, and soundness of articles produced; but it was rejected in

the Lords. This circumstance greatly irritated the people who made fashioned hose, and who were reduced almost to beggary, for there were about that time 2000 wide frames making large quantities of so-called spurious work at Sutton in Ashfield. Again, in 1819, intense suffering recurred, and a large body of soldiers was sent to Nottingham. 7000*l.* was subscribed for relief there, and 6000*l.* at Leicester, after eloquent appeals by the Rev. R. Hall, and others, to relieve the unemployed hands, which then amounted to one-third of the whole.

A bill passed the Commons in 1819 for putting down cut-up work in hosiery; but it was rejected by the Upper House. In 1821 an Act passed both Houses for making agreed lists of prices binding; but it soon became ineffective. Scarcely any hose were made in the three countries during that whole year. A strike took place, and unemployed male and female stockingers drew loads of coal from pits to the towns to obtain alms. In 1824 a great turn-out took place, and the national trade panic of 1826 produced a further downfall in wages. Scarcely any fancy hosiery was now worn, the fashions in dress being less and less in their favour. Orders were rather for plain goods, easy of execution, and not liable to great fluctuations of value in stock. These considerations, added to the increasing rapidity of transit and communication throughout the empire, began to bring buyers and orders, both for home and foreign demand, to the local seats of manufacture, to their great ultimate advantage. Leicester was the first to realize the fact, in the impulse given to its improved

warp frames by the application of Dawson's eccentric wheels, which enabled the makers to produce innumerable articles, from stout woollen webs for breeches pieces, and gloves, braces, cravats, and sashes, to the finest and lightest fancy silk or cotton tissues and nets. The wages for heavy warp goods in 1800 were 2*s.* 6*d.* a yard; in 1816, 8*d.*; in 1819, 4*d.*, when 1500 frames ceased to make them. The close of the war, by which they had been employed, explains this depreciation.

Woollen and cotton socks had begun to be made at Leicester in 1810, giving employment to an increasing number of hands at an average of 10 per cent. over the wages of those making hose. Woollen shirts began to be an important article there about 1815; and cotton and spun silk vests and drawers at Nottingham; and have continued to be manufactured extensively ever since. Knotted hosiery was made at Leicester in 1817, but a change in fashion had brought down the wages in 1825 from 16*s.* to 6*s.* per dozen.

From 1826 temporary strikes and variations in wages succeeded each other almost every second year till 1833, when wages were at the lowest point ever paid in the trade, and the pressure threatened serious results. There were then known to be 33,000 frames in the United Kingdom, from which the entire returns were only about two millions sterling. The 73,000 hands, men, women, and children, were for the most part ill-clothed, ill-fed, poorly lodged, physically deteriorated, mentally depressed, and often morally debased: easily distinguished by their careworn faces from all other

handicraftsmen. The enumerations of frames had hitherto been of those at work only; but as those unemployed were for some years one-third of all the machinery actually in the trade, they had been practically engaged in lowering the wages of those who were at any time at work. Between 1824 and 1832, 4000 frames were sold for about 5*l.* each, a price that the two years' rent charged would cover, and even the low wages were largely paid in goods by many of the under masters. The total poor's rate for the county of Leicester in 1844 was 95,315*l.*, while the frame-work knitters paid in that county the same year 129,206*l.* for frame rent and shop charges. After thirty-five years of such privations and deferred hopes, it is no wonder that the stocking weavers sympathized with the National Charter then propounded, and said that any change must be for the better. Thousands collected in Nottingham, but returned hopeless to their wretched homes, for distress pervaded the entire trade. The sufferings which the writer had long witnessed led him, at much labour and expense, to collect and publish as accurate statistics as possible of the machine hosiery manufacture. This required visits in 1844 to the stocking frames in 240 parishes in the counties of Nottingham, Leicester, and Derby, to ascertain the width, gauge, work, and wages of each. The figures and facts thus obtained were read at the York Meeting of the British Association that year, and have been several times given in evidence to Parliamentary Committees and Government Commissioners. The following figures were ascertained:—There were in Leicestershire

20,861 frames; Derbyshire, 6797; Nottinghamshire, 16,382; elsewhere in England, 1572; in Ireland, 265; and in Scotland, 2605: total, 48,482. Of these 6843 were unemployed. If all were at work there would be upwards of 100,000 persons, more or less, engaged; of these about 15,000 were shop masters, and 33,000 journeymen and apprentices; using up in 1844 imported raw materials costing 304,800*l.* and of home-grown 400,980*l.*; together, 705,780*l.*; wages, expenses, and profits were 1,856,933*l.*; and the total returns 2,562,713*l.* The workman's clear weekly earnings for sixty-six hours' labour upon worsted and cotton hose were under 6*s.*; gloves, 7*s.*; drawers and shirts, 7*s.* 6*d.*; plain silk, 7*s.* 3*d.*; knotts, 8*s.*; and gloves, 7*s.* 9*d.* This document, showing, from an unbiassed independent source, such a miserable rate of wages, justified 25,000 frame-work knitters once more to ask the House of Commons for inquiry, and it was granted. The very brief statements of inventions made in previous pages of this paper show, that the miseries endured by the stockingers did not result from lack of skill or energy in adapting or improving their machinery; and we shall see hereafter that the entire machine-wrought lace manufacture sprung from ingenuity derived from or displayed in the stocking loom. The causes of low wages were undue competition, arising from the parish apprenticeship and construction of needless frames to secure rent; middle-men (bag hosiers) making full charges for partial work; and payment of wages by truck. All these sources of evil have been gradually exposed, and have nearly passed away. Both Inquiry Commissioners

and workpeople opposed making the cut-up hose; but the event has proved that by their low cost they have been pioneers to the use of full-fashioned goods, the enlarged demand for which has increased wages and profits rapidly, and to an extent little anticipated by the most sanguine. Connected with this desirable change the Leicester hosiers (slowly followed by the Nottingham trade) have raised a new and wonderful demand for novelties in colours, patterns, and execution —in a word, have made hosiery again fashionable. In 1850, 1500 frames were producing fancy hose there at 20*s*. a week wages. Twenty-five years ago, one pair of frame-knit hose only was required by each person at home in a year, and the exports were ridiculously small. There was room, therefore, for a great increase of demand and production.

An English synopsis of the French laws on establishing Courts of Conciliation, having been drawn up in 1835, and extensively circulated, they were thought by the frame-work knitters to be specially applicable to their condition; but the idea was for many years discountenanced by their employers. It was not until 1861, when wages had been for some time rapidly rising as the result of constantly increasing demand, that a voluntary compact was entered into by the hosiers of Nottingham and their workmen, to establish and be bound by a board composed of an equal number of delegated masters and men, with a master as chairman and a workman as vice-chairman. This has been found hitherto a satisfactory method of adjusting wages and settling disputes; and is especially important,

because since 1845 the factory system has been introduced, along with more and more new machinery of complicated rotary movements; great width in some, and many cylindrical heads in others, all working by steam, and at high speed; the production from each being under the inspection of one workman or workwoman. This is producing such an absorption of the country population into the larger towns, that an entire change in the arrangements and management of the business in these important particulars seems to be before long inevitable.

Strenuous and persistent efforts had been made from 1825, with the view of working hosiery machinery by hand rotary power, requiring of course new adjustments of the essential operative parts. Success having been attained, steam was soon employed, and the factory system necessarily followed. In the *wide*-frame department, the trade is indebted, for progressive steps, to the several machines constructed by Warner, 1829; Mather, 1831; Foote, 1835; Cope, 1836; Coltman, 1837; and amongst later and more important ones, Luke Barton's and Paget's rotary modifications of Lee's frame deserve especial mention. The latter are working by steam power, narrowing without loss of time, and producing excellent work—the *beau idéal* of the original frame, made self-acting. The thread carrier, now universally used, is a most necessary instrument for increasing the speed of all wide frames. The invention belongs to one, or probably to both, of two stocking weavers—Sadler, who died, aged ninety,

in Mansfield workhouse; and Roe, who died in prison at Nottingham.

It is impossible to find space for a recital of the claims of all those who have been engaged in this series of inventions: for except in the kindred machine-wrought lace, so arduous and expensive a course has scarcely been witnessed elsewhere. The more striking modifications were as follows:—

Thornton took out three patents for *coarse* looped work, being a close imitation of hand-knitted articles; and the produce continues in great demand.

The tumbler needle was one of the most curious and useful of several inventions patented by Townsend, originally a frame knitter, then a hosier at Leicester, and ultimately in the United States, where he met with great success. The one in question consisted in affixing on the frame needle a small moving pin, hinged just so far from the hook as that its point may reach the hook, lying in a spoon-like indent; and, when reversed backwards, may lie in a groove, pointing towards the stem of the hook. The admirable operation of this instrument must be seen to be fully understood; but its importance is such as to be used largely in England, France, Saxony, and the United States. In 1854, Hine and Mundella, with L. Barton, patented a wide ribbing machine, on which ten hose could be made at once; by which labour and cost were diminished and production increased. In the same year that firm in conjunction with Onion, patented a plan whereby the speed of Lee's frame was doubled, and further, in 1857,

an improved method of making ribbed webs, with both sides exactly alike, as also a stocking frame, in which nearly every part is adjusted, according as plain or ribbed is desired. Even a highly skilled mechanic will find that much study is needed to form a just idea of this machine. In the same year Brooks patented a rotary ribbing machine upon an excellent plan, and which has been worked to profit.

W. Cotton patented, in 1863, plans for widening and narrowing hosiery webs, upon horizontal self-acting rotary power frames, in which the operations of the knitting part of the machine are reversed, and so compactly arranged and compressed, as to work safely in the compass of six inches square. It is a first-class piece of machinery; and the right to use it, or permit its use, is vested in the Nottingham Hosiery Company and J. and S. Morley.

Mr. Mellor, once a journeyman frame-smith, and an excellent mechanic, settled in Nottingham in 1844 as a constructor of hosiery machinery. He had already made a wide frame producing six hose at once, and had also put a thread layer to the old wide Sutton frames, and enabled them to make *selvaged* heels. In 1865 he constructed his first wide-fashioning rib machine, on which one workman can produce twelvefold over the first Derby rib frame. Subsequent improvements by Mellor, of this class of frames, have done much to increase his fame.

Attenborough, who has also established a wide reputation for his admirably-constructed hosiery machinery, affirms the fact that all tools must now be of the most

exact and scientific character. The divisions in the long bars of wide frames, and of the rims in round ones, must be mathematically perfect to do the work justice; therefore no expense is spared to attain accuracy in models and perfectly smooth adjustments, to secure the safe and rapid movements in these intricate constructions. This is the more necessary, because finer gauges are required; and therefore lesser spaces can be allowed, for harmoniously working the thousands of instruments of which they are composed. This firm has built self-acting frames, each making twelve six-inch Derby rib webs at a time. They make thirty courses a minute, and produce 300 dozens of rib tops in a week. One man superintends two of these machines. Deviations in the kinds of ribbed work are made by alterations on the surfaces of the wheels that revolve at the ends of the frame.

There still remains that singularly novel, swift, and simple construction, the *round* hosiery frame, invented and patented by Sir I. Brunel, in 1816. A seamless sack is made upon it, and the needles are bearded, and in shape like Lee's. They are fixed on the outside rim of a wheel, placed on a rotating spindle, at distances corresponding to the quality of the desired web, and similar loops are made on them by the operation of sinkers, as in Lee's frame. Yarn, suitably placed, is delivered and pressed down, forming loops between the needles, and carried under the beards. Then the loops are obliquely pushed back upon the needle stems, while another instrument carries a small wheel with long teeth like radii. The solid part of this wheel

presses in succession the needle beards into their grooves, and, taking the web already formed, slides each stitch over the needle heads. Another wheel follows, and puts back the loops clear of the needle beards. Several sets of these wheels may be fixed round the spindle-wheel, and being separately supplied, may each take its spiral course after the former, thus in proportion increasing the speed with which the round sack is formed. The diameters of the spindle-wheels, and resulting sack, may be from two inches to a hundred or more. The work is too rapid to be followed by the eye, yet almost noiseless, and is only interrupted by the breaking of a thread or a needle; and the produce of each head is astonishing. Brunel seems never to have put this invention to a profitable use, and his biographer, Dr. Beamish, says, "It appears not to have come into operation in this country." But so far from this being the case, it has mainly helped to revolutionize the hosiery trade everywhere. The round frame was first seen in Nottingham in 1840, and attracted little notice. In 1845 Mr. Peter Claussen brought thither his patented improvement of it, capable of producing different patterns and using *steel* needles, and in 1847 he patented the apparatus for winding up the web. But instead of requiring tribute for his modifications only, he claimed it also for originality of principle. This was resisted, and he did not go to trial, taking in consequence no profit by his undoubted improvements and their wonderful results, though to him is owing the practical use of this great invention of Brunel. Claussen, ingenious

but unfortunate, overworked his brain, which, added to his want of pecuniary success, drove him into Colney Hatch Asylum, where he passed his last years in much cheerfulness and comfort, and died there in 1872.

An important alteration was made in the round frame by using wheels only, whether in supplying yarn, looping, pressing, or carrying the loops over the needle heads. By the use of the *tumbler* needle, working in grooved cylinders, the raising them up, feeding and subsequent processes, are all effected most accurately on the needles themselves. This machine was adapted to produce Derby ribbed work, especially in colours, and of cotton and merino materials. A workman named Thompson made this ingenious and useful arrangement, and in 1853 Hine and Mundella patented it. Haddens made further improvements in it. Gist, an American citizen, patented a circular frame in which eight feeders could be worked instead of one; and striped work of sixteen colours was produced on a head four inches diameter, making 350 rounds of loops, or a yard in length of web, in a minute. Females can superintend these frames.

Attenborough constructed in 1866 three kinds of circular machines. One with three heads, each having ten feeders, revolving once in a second of time, produces 96,000 loops every minute—equal to 600 square yards of web weekly; another, a shirt frame, 54 inches in circumference, with thirty-two feeders, making ten revolutions, or 297,000 loops, per minute. This requires 100 lb. of yarn daily, or ten tons a year. Its weekly production would cover 1000 square yards; and one firm

sends out a waggon-load daily of these round webs made up into shirts. The third machine is a coarse gauge, also using a tumbler needle, and produces a good imitation of Aberdeen hand-knit hosiery.

Mellor improved Claussen's frame by placing the needles upright instead of horizontally, and operated on them outside by an indented loop-wheel roller; and in 1849, by placing another similar wheel to follow the former, causing it to work more safely and speedily. In 1865 he brought out a curious mechanical combination, described as a circular and selvaged *three-press* broad-ribbing frame, considered highly creditable to the constructor and profitable to the trade. It will supply 320 dozens of rib tops weekly.

The varied and beautiful articles produced from the wide and the circular plain and ribbing machines are largely and constantly increasing the demand for English hosiery. This necessarily requires an equivalent expansion in the supply of yarn spun from cotton and animal wool. The factories and warehouses at Nottingham and Leicester have greatly increased in numbers, extent, and architectural beauty. The houses for workpeople are gradually becoming more healthy and comfortable, but not equal to what they ought to be when compared with the present rate of wages, and there is a marked improvement in the physical appearance of the frame-work knitters and their families.

One of the most peculiar features in the present state of the hosiery manufacture, and which must not pass unnoticed, is the almost extinct condition of the silk branch of the manufacture. When waistcoats, small-

clothes, stockings, and gloves made of silk upon the stocking frame were fashionable, there were about 7000 machines employed on them, and the average earnings had been 18*s.* a week. In 1844 there were 756 frames making silk hose, and 698 making silk gloves in Derbyshire; 687 silk hose, and 1407 glove frames in Nottinghamshire; and 223 elsewhere: in all about 3770. In 1866 they had been reduced to 135 (and with these only one apprentice, in Derbyshire), while scarcely any silk goods were being turned out at Nottingham. The introduction of slight materials weighted with dye stuffs, and change of fashions, have been the principal causes of this cessation in demand.

In 1851 the returns of the British hosiery manufacture were computed to be 3,600,000*l.*, which increased in 1862 to 6,480,000*l.* The Nottingham Chamber of Commerce reported that in 1868 there were more than 40,000 narrow hand-frames, the wages from which were from 6*s.* to 24*s.* a week; wide hand-frames, 16*s.* to 30*s.* weekly. Rotaries are from 40 to 120 inches in width, and are worked in steam factories for 56 hours per week. Of these there were 1200, all attended by men earning from 20*s.* to 30*s.* (many now earn up to 50*s.*), and there were 1500 sets of circular heads employing 2000 to 2500 hands; the men earning 20*s.* to 35*s.* (now up to 60*s.*), and women 12*s.* to 20*s.* (now up to 25*s.*) weekly. There were then also 300 warp machines making hosiery in factories, in which youths and men earned from 16*s.* to 35*s.* (now up to 50*s.* a week). The large further increase in power machines and in price of labour has brought up returns

in 1872 to 4,000,000*l.*, giving employment to about 40,000 adult males, besides 100,000 women and young persons in seaming, cutting, stitching, mending, and otherwise finishing the goods.

This machine hosiery manufacture is spread over 500 communes in France. Their silk hosiery frames are employed in and near Vismes, though the number and amount of production seem not to have been ascertained. In 1866 there were at and around Troyes 10,400 frames, 7800 using cotton, 1400 animal wool and Cashmere, and 1200 spun silk. For materials 295,000*l.* was paid; for wages and profits, 396,700*l.*, making a return of 691,700*l.*; 11,720 men and women were employed, whose average earnings were 5s. a week; and 21,400 women and children, gaining 2s. 3d. a week. The quality of the work is very good. The French purchase but little English hosiery.

In Saxony the hosiery manufacture has rapidly increased from 1800, when there were 20,000 frames, to 30,000 in 1851. In that year the first round frame was introduced; in 1863 there were 4560 cylinders, employing 1335 stitching machines, one house making 30,000 dozens of cut-up hose weekly. There were then 27,000, chiefly narrow hand-frames, and 30 with power rotaries. The rates of wages and amounts of returns are rapidly increasing. The articles made are chiefly for exportation. There are probably 2000 frames in Italy, and 7000 in Spain, making silk goods, besides many in Austria and the north of Europe. In the United States woollen hosiery is made at German Town, and produced in 1866 a yearly return of about

1,800,000*l.*; New York returns 2,500,000*l.*, and New Jersey 300,000*l.* New England is likely to surpass them all. So far as known, the total production that year was about 4,500,000*l.*, and the manufacturers are perfectly cognizant of and use our latest improvements, as well as their own.

The Machine-wrought Lace Manufacture.

When entering upon the subject of the fabrication of lace, it may be remarked that Nature herself has given examples of exquisitely beautiful and varied forms of geometrical and floral networks. The former are revealed on the icy pavements and in the snow; the latter strike the eye and the imagination, when looking on the elegant frost-work which covers the window-panes in a winter's morning. Not less was the Eastern mind charmed with the intricate involutions assumed by the veins in the foliage of many plants—as exemplified, for instance, in the *lace-leaf* of Madagascar. The reticulations of the caterpillar's home and in the spider's web would early lead to efforts after imitation; and these ideas are strengthened by the fact, that the kindred art of embroidery was practised in Babylonia almost from the Flood; and that ornamental network borders and fringes are of nearly equal antiquity. Early in the Christian era open cut-work lace was wrought almost all over Europe, and often of a really elaborate character. The art of making lace by hand on the pillow is said to have been known before 1495 in Flanders, and at a later period

came to France and England. But it is more probable that Barbara, wife of Christopher Uttman, dwelling at the Castle of St. Annaberg, in Saxony, invented it in 1561, and taught it to the peasantry around; from whence it spread over all the adjacent countries. She died in 1575, aged sixty; and the invention is recorded on her tomb. Plain lace net is made on the pillow as follows: threads are hung round it in front, each attached to a bobbin from which it is supplied, and acting as a weight. Each pair of adjacent threads is twisted three half turns, by passing the bobbins over each other. Then the twisted threads are separated and crossed over pins stuck on the front of the cushion in a row. The like twist is then made by every adjacent pair of threads not before twisted, whence the threads become united sideways in meshes. By repeating the process, the fabric gains the length and width required. Open and cloth works, thick threadings, and pearlings are introduced, so as to effect all manner of intricate and beautiful designs; but the methods are too varied and difficult for description. The inventors of lace machinery have studied these various processes, and at length succeeded in copying them all. Refugees from Flanders brought pillow-lace making into Bedfordshire.

A school was set up at Great Marlow in 1626: and about 1650 the business was flourishing in the counties of Northampton, Buckingham, and Devon. In 1830, 120,000 persons were employed upon it.

In tracing the course by which lace made on the pillow has been mechanically imitated, it must be

explained that this has been gradually effected by using three very different classes of machines—the looping hosiery, the warp, and the twist-net. The first of these was Lee's stocking frame, as affected by Strutt's added machine, and modified by points (ticklers) acting on each needle to remove its loop, and place it upon the next one on either side, and so produce interstices across the web. Thus, by first making the loops and then the open work, frame-looped net was produced by Frost in 1764. Next, a *spoon* tickler, to cover two needles and remove two loops, was employed by Frost in 1769, making figured net. The twilling machine was amongst the first, on which these and still further modifications were made for producing net, between 1760 and 1780, by Crane, Harvey, and Else in London, and Hammond, Lindley, Holmes, and Frost at Nottingham. It has been said that Hammond first made bobbin-net and an imitation of cushion-lace, after seeing some on his wife's cap. By shifting loops variously he made looped-net, but nothing more. Else and Harvey, in 1770, invented a further improvement called the *pin* machine. The net on all the above being made by using one thread, it was liable to unrove if that was broken. The larger meshes and fine works in the web were now surrounded by gimp-thread needle embroidery—the humble beginning of *lace running*—giving employment to 150,000 females, until it was superseded by machines. Holmes, a stockinger, assisted by Frost, arranged the "two plain" plan to imitate the six-sided cushion mesh, by removing a loop two *needles to the* right, and a loop to the same from

two needles to the left. By varied movements of a rack-handle, patterns were made. This was probably the first lace-making frame ever arranged—yet Holmes died a poor man. In 1777 Frost patented a machine for making square-net, having *fast* meshes, by altering the movements of the Derby rib-frame (one Thompson, a descendant of one of Lee's journeymen, being the last who worked, about 1834, one of these frames). The same year a very ingenious machine was devised, using additions to Strutt's ribbing process, placed on his machine needle-bar; and thus six-sided meshes were formed. This net, when stiffened, looked like cushion-net; when damp, it shrunk like crape. It was named single-press *point-net*, and was afterwards made fast and strong by adding one pressing more to each row of meshes, and then took the name of double-press net. Several clever workmen contributed to the construction of this frame. Flint, a journeyman stockinger, devised it, aided by Taylor, a frame-smith; Rogers, a workman, perfected it, and then Morris patented this, the point-net machine. Flint died in the Poor-house at Nottingham. Morris made a present of the patent to Hayne, his successor in the lace-business. The demand was at first small; but rose so rapidly for the double-press net, as to employ for years 1500 machines, each 30 inches wide, at Nottingham. At length the making of the articles single press and of single yarn, undermined their character and sale, and finally destroyed the most sterling manufacture of lace ever produced from the stocking frame.

The second department of machine-wrought lace is

that made on the warp frame—so called from the use of only warp threads; forming on them, longitudinally, looped stitches, like those on the stocking frame. A series of guides, of the same number and gauge as the needles in the machine, with holes in their ends, were fixed on a bar near the heads of the needles. Above was a warp beam, having as many threads as there were needles, each thread passing through its guide. A part of the machine was so adapted as to form a loop like that which boys make on a string. This alone would have produced only a series of looped strings, but by other movements a spring was applied to each, removing the guides one needle to the right or left at pleasure; and this being repeated in looping, the two next and every next loop was conjoined to its fellow. By this process a solid web was produced, capable of being cut and sewn up, equally with cloth from warp-and-weft weaving looms. Indeed, no other machine is so universal in its products. Threads of all kinds may be used; its speed is unequalled, as only each thread is looped with its neighbour, thus looping at the same moment across the loom, say 150 inches in width. But the use of a warp thread to every needle introduced great facilities for varying the meshes which might be formed on this machine. In 1795, a lace open work was made; and soon afterwards, figured lace, in almost endless variety of meshes and patterns, of durable quality and marvellous cheapness. The lightest gossamer blond silk lace, cotton tattings and edgings, antimacassars and d'oyleys, threaded and pearled, are finished in this loom, and are the pioneers of higher-

priced lace articles throughout the world. In 1810 there were 400 warp looms at work making the lace called Mechlin net, and using cotton yarn costing fifteen guineas the lb., and at four guineas a week wages. This article took for a time the place of point-net. Tarratt, in 1804, greatly improved the warp machine, by setting it upright and using no sinkers. This ingenious man, who employed his talents on almost every kind of hosiery and lace frames, ended his useful life at a great age, in the Charterhouse at London.

In 1791, Dawson applied his now universally known and improved methods to the construction of wheels to be employed in working warp machines. For this purpose they were notched on the edge, and, in revolving, acted on bars by pressing horizontally on them. As these are forced back or allowed to approach, the movement produces a figure in the web which is being made. The principle is that which operated in the organ barrel in use before this, and Jacquard's apparatus, introduced at Lyons soon after. Dawson was a general mechanician: and by working frames at Nottingham realized some amount of money, but, unfortunately, squandered it away. On the expiration of the patent for his invention, being refused its renewal, he destroyed himself. Dawson's wheels were used in 1807 by Orgill, in the warp frame, and spotting apparatus was connected with it by Vickers. Other improvements for making two-course silk net were made by Kirkland in 1809, while in 1811 Morrison, by putting in suitable wheels and dividing bars, produced silk blond, in making which workmen gained at first 10*l.* a week

wages. This article held an important position for the next forty years. Warp pearling was first made in 1816, and continues in extensive use.

About the year 1820, English silk net was very prejudicially affected by the superior dress and finish of French goods, limiting the demand for our articles. The invention by Heathcoat, in 1809, of the bobbin-net machine, caused a still further lessened production of warp goods for a time; and from that period until the present there has been more or less rivalry between these kinds of lace articles. They are so much alike, that in the event of fashion favouring one, it is often replaced by the other, and together they are able to supply the lace trade to the fullest amount and with the utmost celerity. The machinery is gradually assimilating in width, cost, working hours, and power of production each to the other, and equally requires to be managed by highly-paid workmen; the old warp frames being set aside by rotaries 100 to 150 inches in width. Clever workmen, such as Copestake, Boot, Roberts, Read, Hardy, and Herbert, have successively altered these machines. By 1831 the warp-lace trade had attained large dimensions, assisted by Queen Adelaide's public appearance in a dress of Nottingham white silk lace. In 1835, Street, Whitely, and Dunnington, made further improvements; and the Jacquard was applied to it, 1839, by Draper, who produced warp-lace shawls, &c. The quantity got off a 54-inch, in 1830, was fifty square yards a week. Ball, in 1851, produced 1200 square yards weekly from a machine which he placed in the Exhibition. William

Herbert, a frame-work knitter, enlisted in the army, and fought at Bergen-op-Zoom; but quitting it in 1815, worked a warp frame. High wages and careful savings enabled him to buy machines, and to make goods, by which he gained largely, though times altered and his gains were dissipated. Then, by a single warp frame, he realized 50*l.* a week; and gathering up a large sum, he embarked it again in machinery. Another reverse came and deprived him of all. Afterwards he made such profits by working in a bobbin-net machine, that he became, for the third time, a rich man before he died. Whitely patented, in 1839, a partially traversing warp frame. Hemsley, in 1851 and 1854, patented a perfect traverse and selvages. In 1855, Ball exhibited a double-looped beautiful taffeta, made on a circular warp frame—simple, speedy, and productive, at reduced cost. In 1864, Gamble patented a warp frame, which, by shortening the motions, quickened the production; it is, however, too complicated to be described here.

The third, and most difficult and important, class of lace-making machines remains to be described. It is that which involved the problem, how by mechanism great numbers of threads could be made to twist with or wrap round one another; and, when required, to traverse, mesh by mesh, through a part or the entire width of the frame. To solve this was the aim of ingenious frame-smiths, stocking weavers, and point-net hands, who longed for the high honour and certain profit of success.

Hague attempted it in 1777, by using a horizontal *warp*, and winding every other thread on a long wire

to be passed under and over the next threads; but he could only get them half round, and so failed. Tarratt, in 1780, having seen how cushion-lace was made, tried to make twist-net by using warp threads only, and fastened at both ends. On these he endeavoured to get a twist all round one of each two adjoining threads, and then to pass those adjoining threads each round its neighbouring thread, thus getting the crossings, which he proposed to pass by bars and pins to the end of the threads, and so form meshes. He did not, however, effect this result. The effort was made again at Croydon, by Moore, in 1799; and from time to time till 1816 by Nott, Frost, Hill, and Hart, at Nottingham. From 1816 to 1824, Widdowson worked a machine founded on Moore's plans at Croydon, but in which the exact methods pursued are not known. There were threads put at one end on a beam, and all these threads were lifted over and passed under each other at the other end by pins, which being sufficiently loose to be selected, passed their threads in the required directions, but *not* traversed, and the twists, plats, and crossings were carried up to the work beam as they were formed. The result was a slowly-formed but beautiful mesh (Fig. 6), having two thrice-platted pillars of four threads each, and four twisted sides of two threads each. The plan was too costly to be used with profit.

In 1794, Frost used square bobbins, sliding in grooves, with the warp shifting sideways, right and left, to make twists with the moving bobbin threads, to be carried up by points and so make meshes; but the plan could not be worked to advantage. Green and Simpson endeavoured, in 1797, to make bobbin-net,

but their effort was a failure. Intense, unrequited study brought Simpson to the grave by brain fever; and he was soon after followed by Green, from the like cause.

Hayne, a manufacturer, and Pindar, Potts, and Elliott, all from Nottingham; and Palmer, a scientific man at

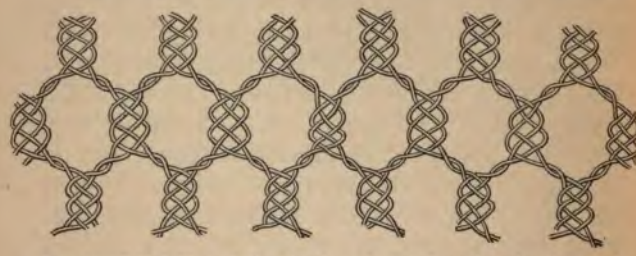


Fig. 6.—Called Platted Net, having platted four thread pillars and four sides of two threads twisted, but not traversed.

Bingham, employed themselves, without success, in endeavours to construct a twisting-net machine. Robert Brown, a frame-work knitter, at Nottingham, patented, in 1802, a machine for producing fast-knotted fishing nets. It was a very ingenious one, taking a work beam and shuttle with other instruments, but using them for new purposes. One of these, called a sinker, carried a bobbin from which the thread was given off, and was held in its place by a spring to keep the thread tight. It was the old weaver's shuttle, reduced into as thin shape and compass as possible at that time. About this shuttle some question afterwards arose. Lindley, Whittaker, Hood, and Thompson, all practical mechanics, each laid claim to its invention. Brown patented, in 1804, a Vandyke web-knitting frame, but it was, like the former, unsuccessful. He

fell into poverty, became insane, and attempted self-destruction. For some years he received 12*s*. weekly from a trade fund; but afterwards was left to pine away in gloomy melancholy, and died in 1818. His son, Alfred Brown, has put together a very complex machine, which seems capable of producing intricate combinations of threads; but his talents are employed under most unfavourable circumstances.

Whittaker attempted, in 1805, to construct an apparatus to make twisted and traversed net, and his instruments are known by a still existing sketch. He wound the threads on bobbins which revolved in cases, placed in combs; these he raised and lowered singly by hand, passing each thread round its neighbour, and pushing up the twist by hand; but in crossing, the bobbins fell out of their places. It is not known that he made any net at all. Though uneducated, Whittaker possessed mechanical talent; but intemperate habits caused him to be uncertain in what he undertook, and placed him in the distressing circumstances in which (prior to 1815) he died. Hood, a hosier, had supplied money to Whittaker, whose materials were given to Charles Hood, a setter-up, a clear-headed but dissipated man, who declared them useless, and endeavoured to construct a machine on a method of his own. In this a twist and crossing were made, but no traverse was obtained. He made twenty yards of net in length and nine inches in breadth, on the two frames which he constructed. He then laid them aside for want of funds. The failure of so many men, distinguished for their ingenuity and misfortunes, did not destroy all hopes of success, though those who in-

dulged them were usually classed with visionaries seeking after the "perpetual motion." It was soon after, that another handicraftsman entered upon, and accomplished, the task that had baffled so many others, and thus laid the foundation of the bobbin-net manufacture, destined to become a highly beneficial and important branch of national industry.

John Heathcoat was the son of Francis Heathcoat, living at Duffield, near Derby, and was born there in 1783. His father was a small farmer, much esteemed for his worth and amiable demeanour. Soon after the birth of this his younger son, the father was stricken with total blindness, causing him to remove, in 1790, to Long-Whatton, and afterwards to Loughborough. He became an owner of warp frames, and his life was prolonged there in comfort to an advanced age. His son received his education from a neighbouring schoolmaster, who was surprised at the quick acquisition of knowledge by young Heathcoat, who united thoughtful intelligence with a quiet deportment. He read much, and laid up a store of facts in history and science, which he used in after-life with accuracy and practical advantage. Early placed in the hosiery manufacture, this was exchanged for apprenticeship with a frame-smith at Long-Whatton, where he learned to handle tools, while he obtained an intimate acquaintance with the hosiery and warp frames; and the latter he soon improved. At the age of sixteen he conceived the idea of constructing a machine to make lace. Referring to this afterwards, he said, "I was working for my bread, and I tried to invent." He felt the

importance of self-help, weighing and accepting the responsibilities attendant on his station in life. Appealing to the Lord Chancellor afterwards, for protection against infringements of his patent, he said, "I had originally no property, and have risen entirely by my own ingenuity and industry." As at that time, 1804, the most difficult and best-paid work in the construction of machinery was to be obtained at Nottingham, he, on the conclusion of his apprenticeship, proceeded thither, and became a journeyman to Elliott, a well-known, skilful mechanician, at 30*s.* weekly earnings, raised shortly after to three guineas. There, artisans used to talk about machinery for making *real* lace; and Elliott said, "Heathcoat showed that he had already attained to a thorough knowledge of mechanical contrivances; was inventive and persevering; undaunted by difficulty or mistakes, and consequent ill-success; patient, self-denying, and very taciturn. But he expressed surprising confidence, that by the application of mechanical principles to the construction of even a twist-net machine, his efforts would be crowned with success." He seems to have devised and executed his projects without any counsellor or co-worker whatever.

He purchased Elliott's tools and goodwill of the business, and thus obtained the highest remuneration of a setter-up at that time. About the same year he married Ann, daughter of William Caldwell, of Hathern, who made him an energetic, intelligent, and excellent wife. Being fully determined, if possible, to realize the construction of a machine for making

twisted and traversed net, he removed to Hathern, where he could secure privacy and quiet, and also the sight, from day to day, of lace making on the pillow, by a Northamptonshire woman, wife of a journeyman living there. In 1805, Heathcoat removed to Loughborough, where Whittaker had failed entirely, and Hood only partially approached success, in attempting to construct a twisting but not a traversing lace frame. During the interval between 1805 and 1808, he perfected his first machine, making net upon it and patenting it. His workmen had seen that it was not a warp frame; though it was not until it was completed that the mystery was cleared up. It was a horizontal machine, and by a semicircular arrangement of threads, instruments, and their movements, the production was effected of a breadth of twisted and traversed net; but only about three inches wide. The motions were tolerably rapid, yet the strip of net was so narrow, that if a wide surface were required, it would be necessary to join breadths together, which would lower the value of the article. This "mechanical pillow," "the most extraordinary machine ever invented," as it was afterwards pronounced to be by Serjeant Copley (Lord Lyndhurst), was at once laid aside, and broken up, and Heathcoat patented, in 1809, his second machine; which, beside producing greater breadth of net, possessed many other important advantages.

In this invention the course of thought seems to have been as follows:—Cushion-made net had half the threads proceeding in wavy lines from end to end

of the piece, and may be represented by warp threads. The other threads lying between the former pass from side to side by an oblique course to the right and left, and may be called weft threads. If the warp threads could move relatively to the weft threads so as to effect the twisting and crossing, but without deviating to the right or left hand, and if the weft threads could be placed so that all of them should effect the twisting at the same time, and one half of them should proceed at each operation to the left and the other half to the right hand (a substitute being also provided for the cushion pins), lace would be made exactly as it is on the cushion, but with great advantage as to speed and cost. The patented machine by which Heathcoat secured these results had two rollers. The lower was the warp beam (Fig. 6, C), on which the longitudinal warp threads are wound. These threads are divided into two parts; each set composed of every other thread, and kept apart by passing through upright guides (F F, Fig. 7) placed at equal distances apart from each other, and keeping the threads laterally at equal distances. They then proceed to the upper roller (D, Fig. 7), the work beam, to which they are tied. Each set of warp threads is capable of motion to the right and left. The bobbins and the carriages in which the traverse threads are placed for conveyance to and fro will be easily understood by Figs. 8, 9, 10, and G G, Fig. 7, in the section of a circular machine.

The bobbins, when in their carriages, and filled with thread, are placed in a row midway between the

two beams (Fig. 11, K; and Fig. 7, G G and K K), so that their threads may arrange collaterally with those from the lower beam. The bobbins contain

SECTION OF CIRCULAR MACHINE.

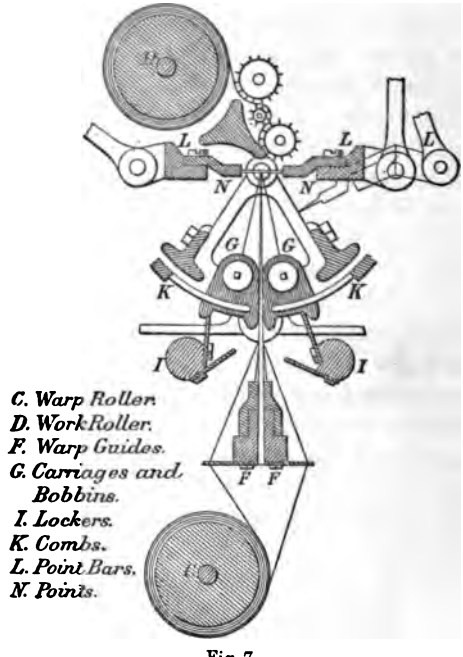


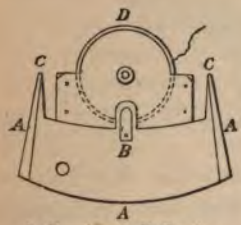
Fig. 7.

space between their sides, into which the diagonal threads are wound (Fig. 8), and are held by spring *f* in carriage, as in Fig. 9.

Two bars are placed to the front and two to the

back of the threads, reaching from one side of the rows of threads to the other, and equal in length to the

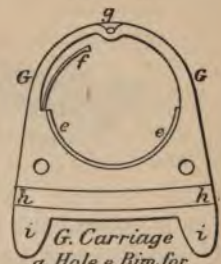
BOBBIN AND CARRIAGE OF HEATHCOAT'S NET MACHINE.



A. Carriage. B. Spring. C. Catches. D. Bobbin.

Fig. 8.

BOBBIN CARRIAGE. CIRCULAR MACHINE.



g. Hole e. Rim for Thread f. Spring h Groove

Fig. 9.

whole breadth of the lace. These bars are each divided (Fig. 11, K) into a number of grooves (combs), running at right angles to their length, and they are so formed and placed in back and front of the threads as to act in the circumference (K K, Fig. 7) of a circle. When the carriages containing the bobbins are placed in the grooves, they are not only kept at equal distances laterally, but they can be made to oscillate along the grooves, through the longitudinal beam threads, by levers called shifting bars, which hang in the centre of the circle, in the circumference of which the grooved (comb) bars are placed (K K, Fig. 7). These bars are called conducting bars.

WEFT BOBBIN CIRCULAR MACHINE.

Fig. 10.

The bobbins are passed half-way through the threads by one of the shifting bars, and received on the other

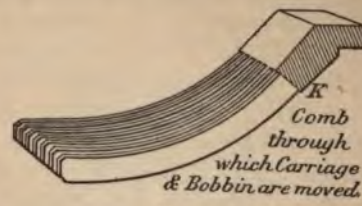


Fig. 11.

side by another similar bar. The twisting of each pair of the threads round one another is performed thus:—When the shifting bars have passed the diagonal thread bobbins and carriages through the warp threads, the comb bar that receives them on the other side has a lateral motion given to it, equal to the space between two threads. If then the bobbins be brought back on the contrary side of each warp thread, each diagonal thread will have made one twist with a longitudinal thread. If now the front comb bar (Fig. 7, K) be moved laterally, till each bobbin stands opposite to the space from which it first started, and the threads be again passed through to the back, and brought again to the front on the other side of each longitudinal thread, the threads will have been twice twisted. Previously to the twistings, one half of the diagonal or bobbin threads must be moved to the right and the other to the left, by which the crossing of these threads is effected by the instrumentality of pins (points) equal in number to the diagonal threads, placed in a bar at equal

distances. These point bars (L L, Fig. 7) and points (N N) are made to move backwards and forwards on an axis with pivots, so that they can pass freely between the threads, and be withdrawn at pleasure. Previous to crossing, every other bobbin is so moved as to form one distinct row, and thus two distinct rows of the whole, one being a little behind the other. The points (N N, Fig. 7) are made to enter the second row; then they receive a lateral motion, till the points are opposite to one division farther to the left of the second row. The points are now advanced through the first row. The effect is, that the right side of the threads of the first row is in contact with the left side of each pin, while the left side of the second row of threads is contiguous to the right side of each pin; thus the diagonal threads are crossed. This has prepared them for again twisting with their contiguous warp threads. The twists and crosses are carried by the points, and suitable movements of the point bars, to the work beam (D, Fig. 7). The twisting with the warp threads, and traversing of the bobbin threads from side to side of the piece of net, give the soundness and durable quality desired in lace; for it could not, as thus made, rove out if one or more threads were broken. On the formation of each row of meshes, the diagonal bobbins and carriages moving to the right will, of necessity, make the end of that row one carriage and bobbin too many, at the right hand; and at the left hand one bobbin and carriage too few. But the row moving to the left will have a reverse surplus carriage too much at one end, and too few at the other end of the row. By an ingenious contrivance

called a turn-again, the machine makes a transfer of these carriages to the lacking end, back and front, thus restoring the full set. By this, though each bobbin and carriage of the entire sets changes its place every series of meshes in width of the machine, their diagonal course is unbroken from end to end of the piece.

Heathcoat showed remarkable decision of character when he threw aside so beautiful a machine as that patented in 1808, because of its confined powers, though perfect in its product, and invented one on a new principle, and increasing the production over the pillow-worker a thousandfold. The warp beam and points of the first frame are the only parts used by him in the second, in a like manner. No model or actual machine or combination of parts used in Heathcoat's second patent had previously been put together, nor had any plan been devised whereby net twisted and traversed from side to side could be made on any machines besides his own. The courses of the threads composing the six-sided meshes of the bobbin-net frame may be easily seen in Fig. 12, where the twists are traced, and where they are shown in the process; and when taken off and extended to their proper shape, as in Fig. 13.

Thus was this extraordinary apparatus devised and constructed by the self-directed talents and unaided mechanical skill of Heathcoat. In accomplishing the task, he met with such difficulties as led him long after to say, that "if it were to be done again, he should probably not attempt to overcome them." The second patent was taken out when he was only twenty-six years of age, a fact that may advantageously act as a stimulus

to young men in any rank of life; inasmuch as this invention was one of the most intricate and valuable ever brought into use. M. Aubrey, an excellent judge, says, "The net made by it is the king of tissues, and is a perfect imitation of the pillow mesh."

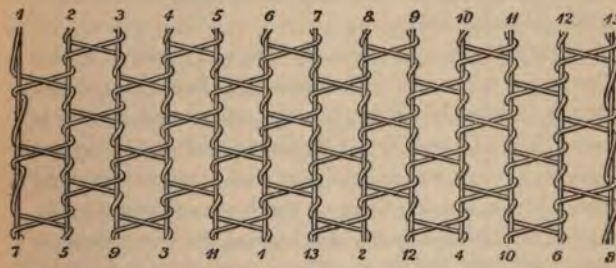


Fig. 12.—Two-Twist Bobbin Net when making, showing the diagonal traversing of bobbin or weft threads.

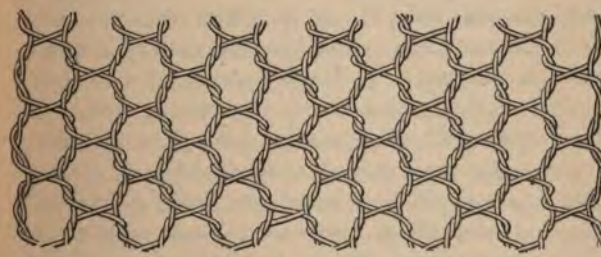


Fig. 13.—Two-Twist Bobbin Net, when taken off the Machine.

The preliminary outlay on these patents was such as to require other aid, Mr. Seddon at first, and then Messrs. Boden, assisting. At length Mr. Lacey, a Nottingham point-net manufacturer (taking the advice

of Mr. Fisher, an eminent London dealer in lace), became Heathcoat's partner, sharing with him the profits from the patent and goods made by the firm upon, ere long, fifty-five machines. The claim to the invention of a machine whose productive powers and consequent profits were very great was not likely to pass unquestioned.

The point as to originality was early put in course for legal decision. The opinion of Brunel, in which Farey, Nicholson, Sylvester, and other civil engineers coincided, adopted by Sir V. Gibbs, and ratified by the jury was, "that when Heathcoat had separated one-half the threads, placing them on the beam as warp threads, and made the bobbins, which carried the other threads, to act between and around those warp threads, so as to produce Buckinghamshire pillow-lace, the lace machine was invented." Among the first and most important infringers was John Brown, who took out a patent in 1811 for a machine called, from its contrary arrangement, a traverse *warp*, Heathcoat's being a traverse *bobbin* machine. This was a very clever reversal of the original, and is the more remarkable for the short interval that had elapsed since the date of Heathcoat's patent. There are the same instruments and the same methods to produce the like results, except that the bobbins supplied the longitudinal threads and the warp beam those threads which performed the diagonal traversing movements. The warp beam was also placed above, the work beam below. Brown and his partners, Nunn and Freeman, brought an action against Moore and Co., who had, marvellous to relate,

constructed in 1812 a fac-simile of their machine without seeing it, and went to trial upon it in 1816. From an error in leaving out a line in the engrossing of Heathcoat's patent, he had been advised not to try its validity at common law; but it was now shown that both these litigants were infringers of his patent, and that his right to it was unquestionable. The cost of this litigation to the plaintiffs was more than 10,000*l.*, and to the defendants 4000*l.* On this trial Serjeant Copley worked Heathcoat's machine correctly and explained it fully, to the surprise of judge, bar, jury, and spectators; and his masterly conduct of the defence had an important bearing upon the learned counsel's future career. After this trial, all the infringers paid royalty to Heathcoat until the expiration of the patent in 1823. It is but justice to John Brown to add that to make the warp threads traverse instead of the bobbin threads, was a proof of great constructive genius, and shows a surprising aptitude in overcoming mechanical difficulties on the part of an extraordinary workman. Mr. Babbage pronounced this machine to be a most interesting study, after a two hours' close examination of it in 1833. It was largely employed, not only at Nottingham, until superseded by the Levers' improvements, but very profitably at Worcester and the Isle of Wight; by Brown and Freeman at the former place, and Nunn at the latter. Each of the three became very rich, yet the two first were originally point-net journeymen. In 1833 Nunn put this machinery to make an imitation of French white silk pillow-lace, called "Neige," in which the re-

semblance to real lace was so close that 80,000*l.* profit was made by him from the sale of this article alone.

Returning to Heathcoat and the course that he and others were pursuing in efforts to improve his machine, he himself in 1813 patented a method for producing perfect selvages in the narrow breadths, into which the web of the machine was now often divided. This was done by working in between them lacing threads that could be withdrawn. The number of movements necessary to making a row of meshes was reduced by him and the combined skill of three workmen, Braley, Henson, and Brooks, and still further by Greenwood, whose plan failed from its delicacy, though an ingenious one. After the long course of stocking-frame breaking, described in the former paper, a cessation of Luddism ensued until June, 1816, when nineteen lace machines were destroyed in the shops of Wright and Mullen, and fifty-five more in the factory of Heathcoat and Co., at Loughborough. A workman was fired at, and Towle, who had previously been acquitted of frame breaking, was now convicted, as also Diggle, of shooting with intention to kill, and were executed. Finally, out of eight of the men who conspired in the attack on Heathcoat's factory, six were convicted and hung at Leicester, and two transported for life. Two of the most active leaders of the Luddites, to save their own lives, gave evidence against them, and deposed that 100*l.* was to be paid for "the job" to the seventeen men told off to perform it. On a legal inquiry into Heathcoat's loss it was assessed at 10,000*l.*, to be paid if he would re-expend it in the county. He refused

to do this, and never received the money. He at once purchased a mill at Tiverton, and there, driven by the Exe and steam, 200 to 300 machines have been worked up to the present time, the wages and profits on which, together with about 400 more in the West of England, have been lost to Leicestershire for half a century.

In 1817 Lindley also applied rotary steam power to his bobbin-net machinery, which consisted of a ruinously expensive patented modification and union of levers and traverse warp frames.

The results of the events that caused Heathcoat's removal to Tiverton proved highly favourable to his interests. He constructed his new frames of increased width and speed, and by applying rotary power lessened the cost of his production. At this time he patented a rotary self-narrowing stocking frame, thus forestalling the efforts put forth since 1845. In 1816 he put gimp and other ornamental threads into bobbin-net, by mechanical adjustments. His workmen now had only the labour of controlling and supplying the machines with materials, and in this he was soon imitated by the principal infringers. Though their production, added to his, obliged him to reduce his wages from time to time, yet the greater part of his hands, having gone with him to Tiverton, continued and prospered in his employment, till they were removed by easy circumstances, age, or death. They have been described by an eminent foreign visitor as "a little world of workpeople, who loved their employer like a father."

In 1818 there were 696 licences granted for machines producing about 10,000*l.* a year.

Heathcoat had 147 machines; Lacy, now separated from him, 127; in all there were 970, and the quantity of bobbin-net made from them rapidly lowered its price. The patentees and their licencees agreed, by a deed in 1819, to prevent the construction of more machinery; the prices of nets were to be regulated by a committee chosen from large and small owners of frames; these being then from 3 quarters to 8 quarters in width. Some journeymen had earned, in 1812, from 6*l.* to 13*l.* a week; in 1815, from 6*l.* to 8*l.*; in 1818, 3*l.* Wages fell in 1824 to 2*l.* weekly. Wages and prices of goods were paid at so much *per rack;* which consists of 240 meshes in length of the web. The name is derived from a circular wheel, one tooth in which is moved forward in every row of meshes that is made.

In 1817, journeymen received 1*s.* per rack for each nine inches in width of the machine; in 1820, 4*d.*; in 1824, 2*d.* The masters received in sale of the nets, 5*s.*, 1*s.*, and 6*d.* respectively. In 1823, 1008 machines were paid for under the expiring patent licences, and it was proposed, that when the supply of net exceeded the demand, a stint of hours for labour should be enforced in future.

Boden, who had been Heathcoat's partner since 1816, quitted the Tiverton business in 1821, and became partner with Grace. This connection being soon closed, Boden joined Morley, a clever mechanic, and laid the foundation of a business at Derby, in which 170 wide and excellent rotary machines were con-

structed by Morley, and which have exercised great influence in the trade. Boden's family having many years after purchased Morley's interest in the property of the firm (for, it is stated, 70,000*l.*), carry on the manufacture, which is chiefly of plain nets.

Heathcoat continued to show unwearied energy in employing his mechanical skill. In 1824 he took out patents on the following matters:—For ornamenting bobbin-net on the machine; for stamping out discs for the carriages of bobbins, since generally practised; for equalizing the size and shape of meshes in bobbin-net; for an improved arrangement and oversight of machinery in factories; for better winding yarn into a cop; and for reeling cocoons, so as at once to twist the threads into thrown-silk. In 1825, for doubling silk threads as they are reeled from cocoons; and for reeling raw silk evenly from any number of cocoons, as exemplified in a filature of thirty basins at Tiverton, where, in the same year, 35,000 lb. of cocoons were reeled into 3500 lb. of fifteen cocoon thread, which was so even as to be worked up there into excellent silk bobbin-net. Later on, for a method of using additional locking bars and cams in lace machines; and for pearling and otherwise ornamenting net. In 1831, by adding warp needles and guides to the bobbin-net frame, to produce a fabric composed of twisted and looped work. In 1832, for further ornamenting lace web; and in 1833, for passing threads across the warp at the tops of net meshes, as to form cloth-work finings. In 1835, for an adaptation of the net machinery to make plain or fancy ribbons, by weaving

them at right angles to the ends, and from the back and front of the frame. The ribbons stand edgewise and parallel to each other. The shuttles and bobbins are filled with weft thread, governed by springs, from back to front, and *vice versâ*. There is a set of warp threads for each ribbon, passing through treddles and slaies, which clear the way for them. The ribbons pass flat, side by side, upon the work roller. In 1843, he took out a final patent for intercepting warp threads, including a method for making longitudinal cloth-work stripes in nets. After this date, Mr. Heathcoat retired from the mechanical pursuits which had so long occupied him.

He had long entertained the idea that most of the manual drudgery of human affairs could be performed by inanimate motive power. Having become acquainted with Mr. Handley, M.P., their united ideas resulted in the construction, and patenting, of a steam plough by Mr. Heathcoat, in 1832, for a time believed to be the most perfect one. The hope was, by it to assist in the agricultural improvement of Ireland.

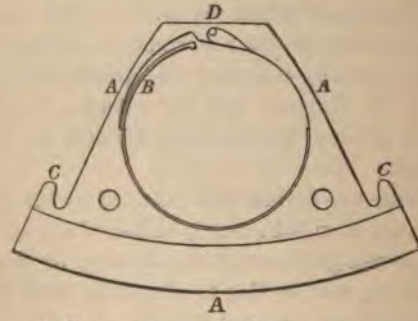
The introduction of the lace business into Tiverton had relieved the place from the effects of the almost entire extinction of its ancient manufacture. The lace factory employed 1200 hands up to 1836, since increased to about 2000. Mr. Heathcoat was elected in 1832 to represent the place in Parliament, twenty years only after he ceased to handle the hammer and the file, and he retained the seat till 1860. He seldom addressed the House, but was eminently useful in committees. His colleague, Lord Palmerston, paid a high

tribute to his patriotic and independent course, on his retirement. He showed his desire for the education of the people by building noble schoolrooms, at the opening of which his address was characterized by its simplicity and moral elevation. His useful life terminated January, 1861; and he was buried at Tiverton, amidst a universal expression of respect and regret. "His upright conduct, love of truth, and ardent attachment to the interests of mankind, endeared him to those amongst whom he lived." His invention laid the foundation for a business which has, within sixty years, mainly contributed to quintuple the population of Nottingham and its suburbs, directly or indirectly giving constant employment to 150,000 workpeople.

A process was devised and patented by Mr. S. Hall, for passing cotton bobbin-net, stretched out to its full width, through gas flames, and so to singe off the superfluous fibres; and by this he cleared at least 50,000*l.* received from the twist-net trade.

A change in Heathcoat's machine was made in 1812 by Clark and Mart, in which every bobbin and carriage was operated upon by an independent pusher, so as to cause it to pass in any desired direction. Further improvements were made by the patentee and several other clever artisans in succession, prior to 1840, resulting in cloth works in nets to be afterwards embroidered by hand for shawls, &c. Amongst these were the "Pusher" frames, on one of which Mr. Miller made, in 1828, pearlings for the first time. But the most important alterations ever made in the internal

arrangements of the patent invention, was in the year 1813, by John Levers, who had been engaged in constructing point-net and warp machines at Nottingham. His plan was to enable him to control each and every individual instrument at will; and instead of dividing the bobbins and carriages into two sets or tiers, to place them, when working backwards and forwards, in *one tier* (Fig. 14). By doubling their number in the same



A. Carriage. *B. Spring.*
C. Drawing Hooks. *D. Hole for Thread.*

Fig. 14.—CARRIAGE OF LEVERS' MACHINE.

space, they require to be of half the thickness, while the combs in which they work are equally doubled in number and reduced in space. The general construction of the machine must be free from vibration, perfectly smooth, and accurate in the finish and action of all its multitudinous parts. Twenty to thirty carriages and bobbins are required to pass easily and very rapidly in each inch of width through their combs. In obtain-

ing this extraordinary perfection of workmanship, Levers was ably seconded by his relative Thompson, an excellent and far-famed worker in metals and wood. He did not see the machine until it was supplied with a warp, and his bobbins and carriages with yarn; and then net was made upon it without further trouble or delay. This man's perfect success in the nicety of finish given to these bobbins and carriages added greatly to his celebrity. He showed others the way to fortune, but knew not how to husband the ample resources which he could command by his own talents.

Levers' first machine was 18 inches wide, soon to be widened by him to 54 inches, while in 1872 many were 200 inches in width. The workmen received 5*l.* weekly wages for years, and the master's profits were great. Stevenson furnished funds for constructing the machines for a time. Levers having placed his admirable adaptation of the frame under the protecting care of this house in the lace trade, who could promote the extended use of the article made upon it, prosperity and wealth lay before this able mechanician, but for some unknown reason the aid from Stevenson was suddenly withdrawn, and Levers' position was much altered for the worse. He was employed almost alone, in an obscure upper room, in making those machines for others, the profits on which he ought to have very largely shared, by working them on his own account. He was a kind-hearted man, and fond of company, but irregular in attention to business. He was fully conscious that the machine he had modified was so much improved as to be only in the infancy of its use,

because of the facility it gave for alterations in the kinds of work produced from it, and it is to be regretted that he did not obtain a fair share of the pecuniary advantages realized from his excellent arrangement of the lace machine. After a short connection with Mr. Fisher, he went, in 1821, to Grand Couronne, near Rouen, where he constructed some machines for M. Laforte, by whom and others he was much respected, and he died there in 1848. A nephew, also named John Levers, constructed machinery on his uncle's plan, save that they were not horizontal, but upright, as they continue to be built; by these he gained 7000*l.*, but losing it during a reverse of trade, never looked up afterwards.

The Levers machine, when fully prepared for making ornamental lace breadths, must admit of alterations in meshes, fine works, thick threading, and pearling; to effect which, adequate additions are now (1873) made to the original frame, e. g. 150 top bars, 400 or 600 bottom bars, 50 or 100 threading beams, and a Jacquard machine to govern the whole. There may be also 50 to 500 exceedingly thin perforated steel bars, each guiding its complement of threads to right or left, as the Jacquard cards may direct, by 80 to 100 movements per minute, of course too quick for the eye to follow. Its power of production will appear by the following instance: A machine, 144 inches in width making inch-wide guipure silk edgings, made 2000 dozen yards in a week, selling for 2*s.* 9*d.* a dozen, or 275*l.*; which, allowing deductions, gives an annual return of 13,000*l.* from this single machine.

It will be convenient here to state the modifications in the Levers frame up to 1840. In 1824, Bertie made some selvaged breadths on it; in 1827 Barnes constructed a Levers traverse warp machine; in 1829 Bailey made a *rotary* Levers frame; in 1831 Sumner patented a bullet-hole on it, giving employment to 600 machines; and in 1834 Bertie patented the looping to the bobbin threads of every other warp thread at the close of the mesh, thus making four twisted pillars and looped closings of the mesh, a plan much used for a time. Besides this, Frost's "fender" net, after lying dormant forty years, had been again very largely made.

Water or steam rotary power having begun to take the place of hand labour, lace machines rapidly increased in numbers, width, and speed, as liberation from the patent approached in 1823. Capital flowed into the business of machinery construction from men of all ranks and professions in and around Nottingham. That already at work sold for thrice its cost, mechanics came in numbers to obtain the wonderful wages offered, strikers at a forge got 5*l.* to 10*l.* a week, engineers and tool makers arrived from distant places. Dwellings could not be had, and building ground sold for 4000*l.* an acre. Thousands of pounds were paid in wages to men who had not seen a twist machine, and tens of thousands were forthcoming (for a time) for machinery that could never repay the outlay. There was a maniacal thirst for gain—"a twist-net fever."

Those who actually wrought in the machines, if provident, realized large sums; and not a few bought

the machines in which they worked, and became their own masters. Improvident men rode to their work, drinking port and claret by the way, and were seen years afterwards receiving parish pay, while some ardent but unsuccessful mechanics became insane. When the national frenzy of 1825 collapsed, the effect of this local inflation was fearful. Visions of wealth were at once dissipated; many in and out of the trade fell into poverty, or became exiles, and some destroyed themselves.

The 970 machines in 1820 had become 2469 in 1825, and 3842 in 1829. The latter were owned by about 1300 persons—all of whom, except eight, had once been artisans. The million sterling which their frames had cost was the result of savings. The value of machinery and the price of bobbin-net fell with great rapidity. A reduction of working hours from twenty to twelve was adopted by seven-eighths of the trade, which in twelve months raised the value of nets about twenty per cent. But many machines being found in course of construction, the makers of net at Nottingham returned to twenty hours, as at present, working by shifts, though in the west they have continued to work single-handed ten hours a day. In 1831 the number of machines had become 4500—making a return of 3,417,000*l.* that year, and had increased in 1833 to 5000, though with a return of only 2,500,000*l.* Six hundred had been sold for old iron. Wages had fallen to 15*s.* a week, and net was sold at 6*d.* a square yard. In 1836 the number was reduced to 3800, and the returns to 2,200,000*l.* Four hundred

owners of one machine each had now disappeared. This distressing state of the plain-net trade hastened the use of the Jacquard for the production of fancy goods. The depreciations in wages and value of products are well exemplified by the following narrative:—Wheatley and Co., of Chard, lost by a fire in 1825 their machinery, valued at 40,000*l.* They replaced it by seventy-two 12-quarter frames, which covered their loss by the first year's work. Riste, once a workman and then a partner, stated in 1838 that he had himself received 26*s.* for making a yard of net, which sold for 5*l.* In 1836 a yard of the same quality would cost for labour one farthing, and was selling in the Nottingham trade for 4*d.*

The *plain* bobbin-net manufacture was depressed in 1840, and still more in 1845, when good machinery was sold at one-twentieth of the price paid for its construction. A national trade panic occurred in 1848, causing further loss in this branch of the Nottingham trade. The amount of plain-net machinery employed in it has declined, until at the present time (1873) it does not produce a fourth part of the total returns of the business, and this may probably be its proportion for a long time to come.

To this, bobbin-net lace ornamented by the machine has, on the contrary, presented a striking contrast, the course of which it is necessary now to trace.

Tarratt and James Sneath, Nottingham, frame-smiths and good mechanics, had assisted Brown and Freeman in constructing the warp-net frame. Sneath, after helping Moore with his platting machine, worked

plain-net frames to profit at Mansfield. His brother, William Sneath, a warp-lace maker, discovered a method of making basket-work *spotted* bobbin-net, profited greatly by his skill, and retired to Canada, where he is living in comfort. Spotted articles are too beautiful ever to go out of fashion.

A patent was taken out in 1836 by Alcock, embodying eleven improved methods of making spotted nets, on circular, traverse warp, and Levers frames. This specification fills 183 pages and thirty-one large sheets of drawings; and is remarkable, as showing the result of self-taught mechanical genius in one who began life as a common labourer. Alcock's uncle, Henson, had a still more singular genius for mechanical construction. Born in 1786, he was first a point-net workman at Nottingham. Then he tried to make lace by twisting threads from bobbins; and, with one Hill, at Huntingdon, put together a frame for lifting threads over each other, but it did not succeed. Henson knew Whittaker, and says that he could not make net; but that he himself made, in 1812, one mesh at a time in a row, by using bobbins and carriages each with two springs, shogging by a bar, and a turn-again—making two or three inches of net. Funds failing, he met with Braley, who could not perfect his attempted improvement of Heathcoat's frame, which he (Henson) accomplished in 1814. He made one for breadths, in 1816, doubling the production; in 1826 he built his rolling locker, reducing the twelve movements between warp threads to six; in 1832 he patented double-headed stationary guides, and also a combined single and double

tier lace machine—forestalling (as he asserts) Draper's invention, afterwards described. In 1833 he patented a fluted roller lace frame; in 1840 he patented improved warp-lace looms; in 1845, a machine for weaving at once several calico pieces at right angles to the loom; and, being in the United States in 1849, he invented a machine which, by oscillations of bobbins and carriages, wove many webs transversely to the width of the machine. He also, in 1851, improved the warp machine, and (finally in North America) patented a wide knitting frame; and in England and France, from 1858 to 1862, took out three further patents in the hosiery manufacture. Henson possessed in his eighty-second year sound intellect and memory, and was probably the only one left of those who founded the manufacture of lace by machinery. He appeared to be then dwelling in comfort at Nottingham.

Draper, in 1834, 1835, and 1837, took out patents for Jacquard application to the lace frame. He was the earliest and most ingenious, though not most successful, pioneer, in finding out how every thread in a machine might be as simply and perfectly controlled, as those on a pillow by the fingers of a workwoman. Money failed Draper before he quite accomplished this; but his diversified combinations of lace machinery were the real germs of those which have been perfected by his successors, with great profit to themselves and to the establishment of the trade; yet this clever mechanic fell into deep and unassisted poverty.

By 1840 the application of the Jacquard to the lace machine had been effected. Oldknow, in 1849, added

the use of very thin steel bars, pierced so as to pass warp threads through them; and guiding the movements of each sideways, right and left. Articles are thus made from the narrowest braid to a highly figured lace curtain two yards wide, and requiring ten or twelve thousand cards to produce the pattern. Oldknow granted 1170 licences, and now 3000 machines are using his perforated steel bar invention. The complex operations governed from the ends and backs of Levers' machines, are carried on in a small space, but through their whole width of perhaps 200 inches, safely and exactly; prompt attention being given to remedy any defects in materials or workmanship.

The reader of these papers will now not be surprised to learn that the two departments treated of have together been made the ground of more patents than probably any other; and of legal discussions without end. A list of 720 patents in both now lies before the writer, to which many more might be added. In 1841 Deverill had patented a claim to the first successful application of the Jacquard to the end of a lace frame. Birkin bought the invention from Deverill; but seeing a doubt arise, relinquished his supposed right; and with most praiseworthy spirit, thus restored freedom of action to the fancy lace department, in which direction alone general profit was to be hoped for. He moreover proceeded to arrange plans for making several important classes of lace machine ornamentation. This excellent mechanician had been engaged in early life at the Belper cotton mills, improving his leisure time in reading and mechanical efforts. Re-

moving to Nottingham in 1822, he learnt, while at work in one class of lace machinery, the principles on which all were constructed. Each was realizing to the owners of a machine making fancy laces 20*l.* to 30*l.* weekly; and 5*l.* to 10*l.* a week to diligent workmen. Birkin husbanded both time and money, and taking the tide at the flood, it led him on rapidly to fortune. He was shrewd and persevering, and had taste and judgment in qualities and designs in lace goods; and filled the offices of a juror in the great Exhibitions of 1851 and 1862, chief magistrate of Nottingham for four years, and a Midland Railway director. At his death he left his family a large property.

James Fisher began to manufacture bobbin-net on his own account about the year 1822, and by 1830 had taken out three patents for machines improved by John Levers, jun. In 1831 Crofts became connected with him, and took out eighteen patents, including thirty claims for novelties in methods of construction. One of them specified nine such; chiefly in methods of producing spotted nets and other cloth works. The specification of this "monster" patent occupies 149 folio printed pages and forty-nine sheets of drawings, costing the patentee about 5000*l.* Many of these patented alterations were clever shackles put on the free use of arrangements in the machinery, already well known. A public combination to resist these claims was organized in 1838, and Fisher ceased any further patent interference in the trade. The talented mechanician Crofts, who assisted Fisher with the technical

knowledge necessary in these operations, was after some years thrown on his own limited pecuniary resources, and finally died in 1868.

A singular gifted mechanic, Bagley, originally a shoemaker, when sixteen, learnt to work a twist frame; and at once put on a circular machine, with "Grecian" net. Then he went on to produce various meshes; one of which, "Honeycomb," he showed to Crofts, and it led to connection with Fisher's business. He afterwards put into a machine extra guides for ornamenting "blondes," and these articles were so profitable to others, that he began to make a machine for himself. While constructing it, "he and his wife suffered intensely from hunger; ate meat only once in three months; and sometimes lived for days together on gruel without bread." The machine was finished: and Fisher purchased his inventive talents for 100*l.* each patented plan, and 100*l.* more if four machines were constructed on it. He then conceived the method of using two threads for warp instead of one, and twisting the bobbin thread twice round this double warp, instead of once: thus making a new and most valuable article, called "plat net." For it Fisher gave him 100*l.*, and one licence; putting on many machines himself, and licensing others at a very profitable rate. Bagley now left Fisher, and proceeded to make very excellent nets, ornamented with cloth works, also light Mechlin net; traversed nets, with looped finings; Valenciennes edgings; and Honiton sprigs—the latter first shown to him in Paris in 1850. While walking on the Boulevards, he "accomplished making them in his mind, returned to Nottingham, and put on ma-

chines to make them." He was the victim of a restless appetite for invention, yet was unable to make a reasonable and safe bargain when he had completed one; and moreover, neither kept accounts himself, nor required them from others. It is pleasant to record, however, that latterly Bagley's position improved with the increased demand for his excellent articles; and with the half-share of his Valenciennes patent, he was enabled to pass his latter years in comfort. His death occurred in 1859.

Sewell, a self-taught mechanical constructor, mathematician, and chemist, began life in the stocking frame, then made point-net, and in 1818 bought a twist-net machine. He improved the speed of this class of frames, so as to make five racks in length of 240 meshes each in an hour. He filled a factory in 1831 with twenty-four 12-quarter steam rotary frames, making fine three-twist net, for appliqué Brussels sprigs; and also good platted nets. He produced ornamented wide nets for the East Indian trade. He is of gentlemanly manners and refined mind, and is now spending his last years in Australia.

Barton was an excellent mechanical constructor, who, after much study, put into operation a machine in which there was no warp, the yarn being all drawn off bobbins. It had five comb-bars and four sets of points, and required 240 movements to complete one row of meshes. The result was an article equal to that from the pillow. But the strain on intellect and nerves cost Mr. Barton his life, and he died by his own hand in 1845.

Waterhouse constructed a very fine gauge machine.

The bobbins could only traverse over two meshes, but by using two warps and two bobbins, a mesh of two upright pillars and four twisted sides was obtained, and a Brussels ground successfully imitated. Unfortunately the high price of the net prevented its use, for the machine cost 3000*l.* in construction, and was sold for 300*l.*

In 1846, Livesey arranged a machine to make net work, composed of looped meshes, the bobbin threads laying hold of the warp threads alternately on each side. This net, not being traversed, is called straight-down net. The tissue is not usually wrought a fast net, but is made so when required. Cloth and open works are introduced in floral and geometrical designs, and thus curtains, antimacassars, &c., are made of any size or price. A pair of curtains, each four yards long, may be made on one frame in two hours. In the Exhibition of 1851, curtains five yards long and two yards wide, each containing only one elaborate pattern, were shown and valued at 30*s.*; the pattern required 15,000 cards to produce it. Tons weight of cotton curtains now leave Nottingham weekly in the season. Elsey, Sissling, T. Birkin, and Cope, all ingenious mechanics, have improved this machine. Livesey took out seven patents, chiefly for velvet ornamentation of lace nets; though with much aptitude for invention, he was more suggestive than practical, and reaped for himself little advantage. He emigrated to Australia, where, in 1866, he was living in comfortable circumstances. More or less close approaches to real cushion-lace have been made since 1866, and all of them patented; but from

their intricacy it would be impossible so to describe them as to be generally understood, in addition to the difficulty of assigning to each modification its true position in these minute changes. We seem, however, drawing near to the time "when the lace machine shall become the true cushion-lace maker, and its bobbins be the spools worked by mechanical hands and fingers."

In 1843 there were 3200 twist net and 800 warp frames, returning 2,740,000*l.* that year; in 1851, 3200 bobbin net and 400 warp, giving a return of 3,846,000*l.*; and in 1866, 3552 bobbin and 400 warp, returning 5,130,000*l.* There has since been no actual census, but about the same number is now at work, and the returns and profits are greatly increased by improved quality and patterns of goods produced. The returns of 1872 were certainly 6,000,000*l.* at least; and from advancing wages and demand for Levers laces, must still rapidly increase. Men are now earning by making them from 4*l.* to 6*l.* for fifty-six hours' weekly labour.

France took a leading part in the early cushion manufacture of lace; and in 1851 there were 235,000 French cushion-lace workers, who produced 3,000,000*l.* annually, the whole European production being 5,500,000*l.*, by 535,000 workers in hand-made lace. They were equally alert in France to obtain English lace-making machinery. Two thousand of our "pin" machines were soon at work there. Then our "spoon-ticklers" were largely used at Lyons; 3000 point-net frames were long employed on silk net, and in 1826 the Jacquard was applied to their lace machines. In

1815 Heathcoat's machine was set up at Valenciennes, and next year at Calais, both being obtained from England; but in 1824 one was built there. In 1818 Heathcoat constructed his machines at Paris. English improvements have at once reappeared in France, and chiefly those used in making fancy articles. The bobbin-net machines in France in 1856 were 1400, making an annual return of 800,000*l.*, and 350 warp frames, producing 230,000*l.* a year. In 1867 there was an increase; and in 1870 they had risen to 1860 in number, caused by enlarged demand for fancy laces. Recent events in France will probably alter the relative position of this manufacture between the two countries.

In 1856 there were about 50 bobbin-net machines in Belgium, making very fine extra twist net, on which cushion sprigs are applied; in Switzerland about 80, making plain net for embroidery as curtains; in Spain in 1831 there were 500 pin machines, and in 1856, 80 twist-net machines; in Austria, 500 in 1854; in Prussia and Russia, 30; and in Saxony, 60.

On a review of these kindred manufactures of hosiery and lace, several interesting subjects offer themselves for consideration. Among them we cannot but remark the extraordinary amount of latent inventive skill brought into operation by men entirely uninstructed in the science of mechanics, and be struck with the time and thought that the knowledge of sound mechanical principles would have saved them. And further, how uncertain has been the profit derived from even efficient new combinations in machinery, to those who

were the actual devisers of them. Beyond this, it is painful to notice how many of these men, possessing fine natural talents, from the want of self-government, failed to use aright even the measure of profit that reached them; neither securing their own or their families' welfare. Genius was to them rather a curse than a blessing. Here are strong arguments for higher scientific and moral education to be placed within reach of these classes. It is submitted also, that the extent of patent rights, with their costs and effects in these trades, furnish most important matter in regard to discussions now pending, as to their beneficial character or otherwise, which should not be overlooked.

In conclusion, seventy years ago, graceful floral patterns were unknown in the lace trade of Nottingham; now, by the School of Design, there has been introduced a thorough reform in taste; and form, light, and shade adorn our reticulated tissues.

CARPETS.

By Christopher Dresser, Ph.D.

Carpets [Italian, *Carpetta;* Dutch, *Karpet*], like nations, have a history. The palace of the Pharaohs, the temples of Heliopolis, the mansions of Greece and of Rome, the dwellings of Persia, China, India, and Morocco, all had their carpets, which therefore come to us from a venerable antiquity.

Sardinian carpets are mentioned by Plautus, the comic poet, as being spread "beneath the ivory feet of purple-cushioned couches;" and we all remember the description of the magnificent banquet of Ptolemy Philadelphus, from which we learn that underneath two hundred golden lounges "were strewed purple carpets of the finest wool, with the carpet pattern on both sides." At this same banquet we are told that "handsomely embroidered rugs, very beautifully elaborated with figures," were also used, and that "thin Persian cloths covered the space where the guests walked, having most accurate representations of animals embroidered on them."

The Babylonian carpets were much prized, and upon them groups of figures were wrought, together with dragons and other mythical monsters. They were sold largely in Greece and Rome. The carpets of Carthage were also celebrated.

We know but little of the history of the manu-

facture of carpets in China, Persia, or India; but it is more than probable that the Indians derived the art from the Persians, for we can trace the seats of manufacture in India gradually back towards the borders of Persia; and there is not only a similarity between the patterns that adorned the earliest carpets of which we have knowledge from Persia and India, but there is in many cases actual identity; and this sameness of design is constantly met with in the present day in the works of these two Eastern nations. Were there no other evidence, this sameness of pattern between the works produced in these two great countries, which now have their seats of manufacture so widely apart, would yet enable us to perceive that carpets were made at an early time in both Persia and India.

The first carpets known in Europe were carried into Spain by the Moors, who, while leading a wandering life, were great weavers; and the loom seems to have been the peculiar pride of the entire Arabian civilization, to which we are indebted for so many of our arts; while Nomads, the Arabians (and I include the Moors in this term) could weave the most gorgeous tissues and fabrics: and just as the opulent of Khiva and Turkistan now live in large tents hung with gorgeous hangings, so did the Arabians dwell in abodes formed of fabrics which they wrought in the loom; and the dwellings, which they built when they abandoned their wanderings, have walls which we may regard as mere petrifications of their gorgeous tissues.

After the Moorish carpets became known in Spain,

the Venetians introduced them into Italy, and commenced to supply them also to Western Europe. Carpets are frequently mentioned in the middle ages as a luxury of the rich. Queen Elizabeth had in her presence-chamber a carpet spread upon rushes, while Queen Mary had only the rushes; but those which were spread upon the floors of the wealthy before carpets were in use were not the common rush, but the sweet reed (*Acorus calamus*), a plant growing abundantly in Norfolk. I may just mention in passing that one of the charges brought by Henry VIII. against Cardinal Wolsey, was extravagance in the use of sweet rushes.

Chequered matting appears to have been much used about the fifteenth century, and also certain "fringed hearth-rugs of Gothic design."

In the reign of Henry IV. the manufacture of carpets was introduced from Persia to France. Colbert, the minister of Louis XIV., established the manufactory at Beauvais in 1664—the factory which is now in the hands of the Government. The manufactory of Gobelins was established but little later, and was purchased in 1677 by Colbert from the Gobelin family, whose progenitors had brought their art, as was supposed, from Flanders.

An attempt was made during the reign of Henry VIII. to start this manufacture in England, but without much result. Under the patronage of James I. it was more successfully established, and works were erected at Mortlake, in Surrey, the royal patron himself contributing a considerable sum towards their maintenance.

To Mortlake French weavers were brought; but a real success was only achieved after the celebrated edict of Nantes, in 1685, when artisans of every trade sought refuge in this country, and amongst them many carpet weavers.

In the year 1750 the Society of Arts awarded a prize for the best imitation Turkey carpet, and about this time Parisot conducted a manufactory in Paddington, under the patronage of the Duke of Cumberland. Subsequently, carpets were wrought at Axminster; then at Wilton, near Salisbury; and afterwards at Edinburgh; while now the chief centres of the manufacture are Kidderminster, Halifax, and Glasgow, though there are many other towns in which carpets are also made.

In the earliest times they appear to have been spread upon floors, or thrown over cushions with the view of furnishing couches on which persons might rest, and were first applied to religious purposes by the priests of Heliopolis. In the Homeric age they were certainly spread upon the floor and walked upon.

In our middle ages carpets were used as floor coverings and as table-covers in both palaces and mansions, and were most common in the ladies' apartments of the baronial halls, as also spread upon grass, for the purpose of reclining upon. In the reign of Edward VI. we read that before communion-tables were placed

> "Carpets full gay,
> That wrought were in the Orient."

From what I have recently seen, and from what I now know of the customs and habits of the Persians, Arabians, and Moors, I am of opinion that the tents

which gave birth to the architecture of these three nations were formed of carpets similar to those produced in these countries at the present hour. Large quantities of small carpets are still made by all Mohammedan peoples, who prostrate themselves upon them at the hour of prayer; and in South America a vast quantity of small rugs are used to kneel upon in the Roman Catholic churches; but these are made in Yorkshire.

During recent years, carpeting has again come into use as a covering for tables, when it generally has a velvet surface. Of fine quality, and with a similar surface, it has been manufactured in France as a covering for furniture, such as chairs and couches. What is called Kidderminster carpeting is sometimes used as window or *portier* hangings, but, as a rule, carpets of every description are now spread upon floors.

It is difficult in all cases to say of what materials carpets were made by the ancients, but some were certainly of wool. Persian carpets seem invariably to be wrought of worsteds, while the richest of the Indian rugs are of silk. Silk carpets are made principally at that great centre of manufacture, Wurrungal, but also at Lahore and other places. Most Indian carpets are, however, formed of wool, and there are many seats of this manufacture, as Wurrungal, Ellore, and Bokhara. Many are also made of cotton, these being wrought at Wurrungal, Rungpore, and Sasseram; and cotton carpets are also turned out at Ahmedabad, though these have pattern applied to them by printing, and not by *weaving*, as is usually the case.

Smyrna rugs and Moorish carpets are all formed of wool (I do not speak of the threads which constitute the "backing" or groundwork of a carpet in any case), and so are almost all European carpets. Carpets have been formed in England, however, of cotton; and the finest European carpet shown in the Vienna Exhibition of 1873 was chiefly wrought of silk; and it is singular, that while I induced an English manufacturer to procure silk with the view of forming and exhibiting a silk carpet, he failed in the attempt, while it was most successfully made by P. Haas & Son, of Vienna. Carpets have been formed of cowhair, also of strips of leather, and the commonest goods are now made of jute and hemp. Almost every available material has at some time been used for the manufacture of floor-coverings, but wool is now in general use for the production of all kinds of carpets.

The Egyptians made them by picking out from a piece of coarse linen which was already woven, certain weft (or cross) threads, and by sewing tufts of coloured worsteds to the warp threads, sufficient of the weft threads being allowed to remain to knit the warp threads together.

Some of the simple kinds of cotton carpets of India are formed in the most primitive way, but these are without "pile" of any description. Warp threads are placed horizontally, and the loom is without treddles or reed. The weft threads are thrown across by the weaver, and are brought together by a small hand comb.

A similar loom, only placed vertically, is employed

for the production of certain Indian carpets which have a looped surface, and some of the richly figured cotton carpets from Wurrungal, Deccan, are wrought in this simple manner, every loop of the variously coloured cottons being brought up by the hand of the weaver. In such cases he has the drawing of the pattern by his side; but after much practice, he is enabled to form the design without reference to it.

The Persian carpets, and many of those which are wrought in India of woollen material, are formed upon a vertical frame on which warp threads are arranged. Upon the latter, tufts of woollen yarns are knotted, and over each row of these tufts a woof thread is passed. In Persia most of the carpets appear to be made by boys, who are subject to a master-man.

Before the boys commence to weave any particular pattern, the master assembles them before the drawing of the carpet; and from this design, which is on squared paper like our Berlin-wool patterns, he teaches them the arrangement and colour of every thread. When this most difficult of tasks is perfectly learned, each boy has to produce a carpet without reference to the drawing. Had a lady to learn the position of every particular stitch in a Berlin-wool pattern before she commenced her work, our eyes would rarely be offended by the hideous patterns that we so often see as ottoman covers, screens, and slippers.

Turkey carpets are made in a similar manner to the carpets of Persia, and so are French tapestries; only in the latter case, a "shuttle-needle" is used in attaching the woollen threads to the warp.

The manufacture of our Axminster carpets is a mere modification of the Persian method, for here also the worsteds are only knotted to the warp threads.

Axminster carpets derive their name from the Devonshire town at which they were formerly made; but the seat of the manufacture has been long since removed to Wilton.

All the carpets produced by the methods of manufacture already described, save the commoner Indian cotton carpets with unlooped surfaces, are extremely durable. Those from India which have a velvet or a looped surface, whether formed of worsted, silk, or cotton, are almost everlasting, but the silk is more tender than the worsted or the cotton. The carpets of Persia, Turkey, and Morocco, as well as our own Axminster productions, are of the same lasting character, but only few of the latter are now made, as they are exceedingly costly, being much more expensive than the beautiful rugs of the East.

Some few Indian carpets appear to be woven in parts, which are afterwards joined together, the manufacture resembling that of Cashmere shawls; but carpets made in this manner are not general. I am of opinion that some of the Babylonian carpets were formed in a similar fashion; but of this there is a want of conclusive evidence.

All the carpets of which I have already spoken are hand made; there are, however, other kinds which are produced wholly or in part by machinery.

A great alteration in the methods of manufacture occurred, when Jacquard completed the apparatus by

which pattern can be applied mechanically to any fabric which is woven in a loom. By his apparatus, a set of perforated cards suffices for the production of "figure" on any woven fabric. The Jacquard apparatus gives pattern to silks, to damask hangings, to table-linen, to lace curtains, and to many other fabrics, as well as to carpets.

Those carpets which receive pattern by a mechanical contrivance are much cheaper than those which are figured by the hand processes already described; for when every thread is selected by hand, the labour of production must be great, and the process slow and expensive.

Of the machine-made carpets, first came the kind known as "Kidderminster"; but, as in the case of Axminster carpeting, the name is derived from the town where it was formerly wrought, while for years past little or none of this fabric has been made in the first seat of the industry.

The Kidderminster, or, as it is often called, Scotch carpet, has a worsted warp and woollen weft, and is a yard in width. It is a double, or, to speak technically, two-ply carpet, and the double thicknesses are united, or interlocked, at intervals. It is not a very durable carpet, and has but small capabilities of producing pattern. It is best formed of yarns of only two, or at most three, colours, and these should be so arranged as to prevent their appearing striped. An improvement on this is the three-ply or three-fold carpet, invented by Mr. Thos. Morton, of Kilmarnock. This is composed of three webs, which, by interchanging their threads,

produce a pattern on both sides. More variety of pattern is possible to this than to the two-ply carpet, and it is thicker, softer, and more durable.

Brussels carpeting is a great advance on either of the two kinds just named. A Brussels carpet may consist of six thicknesses of worsted, together with certain threads of hemp or other material which knit the worsted threads together, and form the "backing," or back part of the carpet.

While Brussels carpets may consist of six thicknesses of worsted, they are also made of five, four, three, and even two thicknesses, but more particularly of three, four, and five; the six thickness quality being superior and rare.

In the trade, a Brussels carpet which consists of six thicknesses is termed a "six-frame carpet," and, in like manner, one formed of five thicknesses is "five-frame"; one of four thicknesses, "four-frame," and so on.

The reason of this mode of expression is this: the yarn or worsted which forms each thickness of the carpet is, during the process of manufacture, derived from a separate frame of reels or bobbins. The frames of worsted, whether two, three, or more in number, are placed more or less horizontally behind the loom, and in order to supply the worsted for each thickness of the carpet, there is a large frame which is crossed by strong wires, one beyond or above the other, in the manner of the rounds of a ladder, and each wire threads a number of large reels, resembling ordinary cotton reels. Each reel supplies one thread of worsted to the loom, and as there are two hundred and sixty

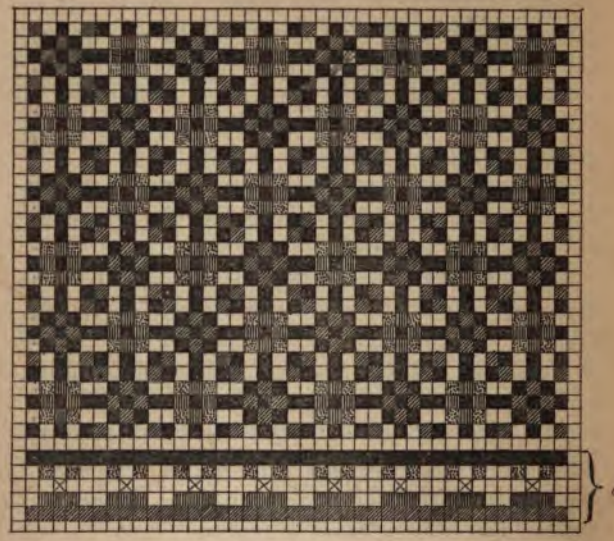


Fig. 1.—Full size rule-paper drawing of a "five-frame" Brussels carpet (a portion only being shown). While this pattern could only be woven in a five-frame loom, it would not require five full frames of yarn in order for its production. Thus, of the dotted frame only four stitches are required out of every ten, or one hundred and four in the full width instead of two hundred and sixty. The white frame would be incomplete where crosses are shown. In this frame two stitches are saved in every ten, thus fifty-two are saved in the width. In the next frame (that marked in the diagram with vertical stripes) four are saved out of every ten, or one hundred and four out of the width. The frame of black, and that indicated in the diagram by diagonal lines, are the only full frames; in the other three a total saving of three hundred and twelve threads is effected, or of one frame and a fifth. Thus a carpet woven of this pattern would be of five frames, yet in quality it would be inferior to one woven with four full frames.

The part marked *a* is called the gammot.

threads in the width of the Brussels carpet (which measures 27 inches), there are necessarily two hundred and sixty reels or bobbins in each frame.

By the Jacquard apparatus it is possible to draw any particular thread to the surface of the woven carpet, and in all cases every colour employed in the production of a carpet is brought to the surface at places. It thus often happens that the number of frames of worsted employed in the manufacture of a carpet is indicated by the number of colours discoverable in the pattern; but this is not always the case, for it is not uncommon to arrange a "frame" of two or three different colours.

If a colour, as, for example, blue, appears only in spots, or in small masses of any kind, and these spots or masses are separated from each other by some distance *in the width* of the carpet, we may feel certain that it does not go all over; but if there are a certain number of colours constantly recurring throughout the entire width of the carpet, then the number of colours in the pattern will give the number of the thicknesses of worsted in the fabric. See Figs. 1 and 2.

The manufacturer seeks to make a carpet look of better quality than it actually is, and thus equal to a quality superior to itself. An ingenious designer will so arrange six colours in a five-frame carpet, that it requires a practised eye to detect that the carpet is not of six frames; or in some cases he will so place six colours in a four-frame carpet, that he will make it look like a fabric of six thicknesses

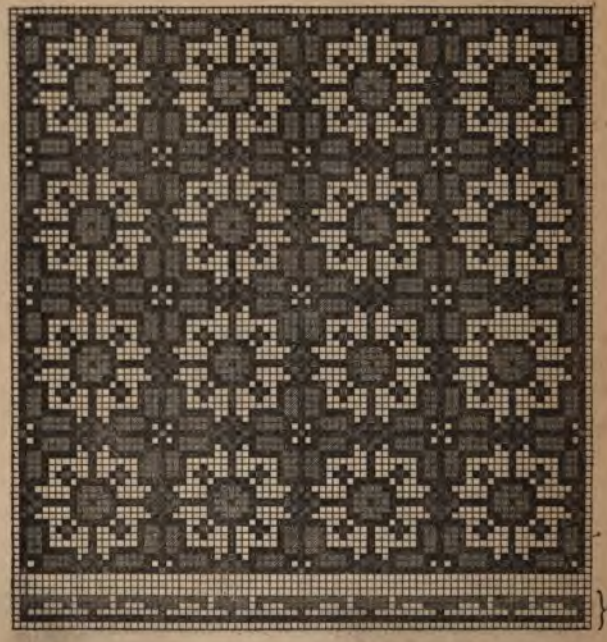


Fig. 2.—Rule-paper drawing (of about one-fourth scale) of a six-colour four-frame Brussels carpet. Let the diagonal lines in the diagram represent one colour, the dots another, the vertical lines another, the horizontal lines another, the white spaces another, and the black another, and it will be seen by a glance at the gammot (*a*), that four thicknesses of yarns are all that are necessary to the weaving of this pattern, while the yarns are of six colours. Frames 1 and 2, counting from the top, are "planted," that is, each of them contains more than one colour. While this is the case, the three first frames are also imperfect. Thus in the top frame one stitch out of every ten is saved, or twenty-six in the entire width of two hundred and sixty threads; in the next frame four are saved out of every ten, or one hundred and four in the width; in the third frame one is saved out of every ten, or twenty-six in the width. The fourth frame alone is complete, yet we have six colours. *The diagram* only represents a portion of the width of the carpet.

to all but the carefully cultured eye. A carpet thus planned commands a better sale than one that looks no better than it is. Fig. 2.

The surface of a Brussels carpet consists of loops, which result from the warp threads being passed over a stout wire, which wire resembles in appearance a common metal meat-skewer with looped end, the wire, however, being 27 inches in length. Such a wire having been placed in the loom, as if it were a weft thread, is covered by the two hundred and sixty warp threads, and then a thin hempen weft is passed across; thus a series of loops are formed over or around the wire, and it is woven into the fabric as though it were a thick weft thread, and it were intended to form a coarse corded or rep-like fabric. Wire after wire is covered by the warp threads and woven into the fabric, till eight or ten rows of loops have been formed around the wires. Now the wire, which was first covered by loops, is withdrawn by a hook which catches in its looped end. Another set of loops is formed in front, and another wire is withdrawn behind; but during the process of weaving, eight or ten wires are always in the last-formed portion of the fabric.

The method by which a Brussels carpet is formed is this: A small drawing of the pattern is first prepared, which drawing (technically called the model) is usually about one-sixth or one-tenth of the size that the pattern will be, when it appears upon the manufactured carpet. This being approved, it is redrawn on squared paper (sometimes called ruled paper), or, to use technical language, is "put on lines." The ruled paper for Brussels carpet patterns has two hundred

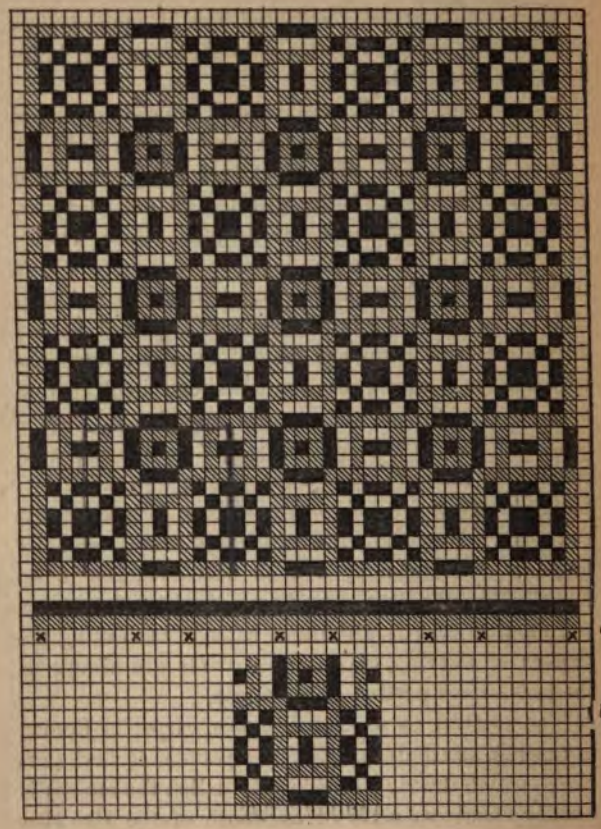


Fig. 3. — Rule-paper drawing of a "three-frame" Brussels carpet. *a* is the gammot. *b* is one repeat of the pattern, or a complete unit of the whole design. While this carpet pattern would be woven by a loom with three frames of yarn, the white frame would be incomplete wherever a × occurs in the gammot.

and sixty squares in its width, each square represents one stitch of the *surface* of the woven fabric. The pattern must be exactly completed once, twice, or more times in the two hundred and sixty squares; for if this were not the case, the various strips of carpeting when joined together would not form complete patterns. The length in which the pattern repeats is unimportant. Fig. 3.

There are, however, what are termed "drop" patterns, and these do not fit together in the usual manner as when any given point in the side of one strip of carpeting joins the point just opposite at the other side of the strip. Drop patterns, like common patterns, join, but the parts of the pattern which fit together are arranged in an alternate, instead of in an opposite, manner on the sides of the one strip. The nature of such repeats will be at once apparent from a glance at Fig. 4.

There are other patterns which will join only at one side. In these the parts of the pattern unite at one side of the strip of carpet only, the other side joining with a similar side of the next strip. When sewn together, such carpets have their alternate strips pointing in opposite directions. Figs. 5, 6, and 7 are of this description.

When the drawing "on the lines" is completed—every square being coloured so as exactly to be a counterpart of every stitch that shall be brought to the surface of the carpet when woven—it is passed to girls called "stampers." These girls are supplied with cards of about 14 inches long by 3 inches in width.

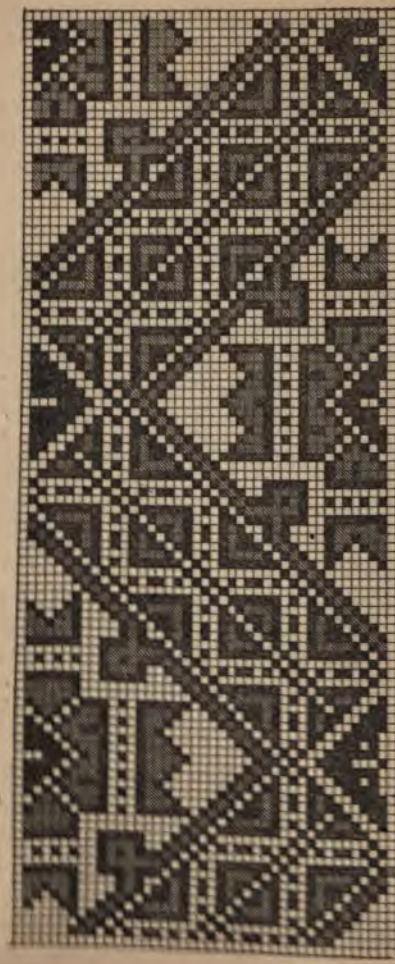


Fig. 4 represents a "drop" pattern. Here the two sides of the carpet are not joined by the next strips on the same level. The pattern at one side has to "drop" to a lower position, to join the part of the pattern which is at the other side of the strip.

Following each row of squares in the width of the rule-paper drawing, they stamp holes in the cards. Holes in certain positions will, by the agency of the Jacquard apparatus, bring up stitches from one frame of worsted in the loom; holes in other positions will bring up stitches from another frame of worsted, and so on: thus stitches or loops can be brought from any frame (they being thus of various colours) to any required portion of the surface of the carpet. Any desired pattern may be produced by the holes in the cards occupying certain positions, but there must be a frame of worsted in the loom, or a part of a frame, as may be necessary, for each colour that is requisite to the formation of the figures.

One card having been perforated for each row of stitches or loops in the width of the carpet, all the cards are fastened together in the manner of a circular band or an endless chain; thus a chain or band is formed of about 14 inches in width, with units about 3 inches deep.

But the man who has placed the pattern on the lines (technically called the "putter on") has prepared a "gammot" as well as the "rule-paper" drawing of the pattern. This gammot is only necessary when full frames are not used throughout, or when one or more of the frames contain two colours, as it is a mere drawing, giving the arrangement of the warp threads for the loom. If a carpet is to be formed of five full frames, each frame being of one colour throughout, the weaver can simply be told that one frame is to be filled with yarns of a certain tint of red, another with yarns of a certain tint of blue, and so on,

for all is here simple, and he requires no further guide to enable him rightly to arrange his loom. But if one or more frames shall contain each two or more colours, he must be shown how many threads are to be of one colour, and how many of another in each particular frame, and where the threads of each particular colour are to be situated in each frame: this the gammot does. See Figs. 1, 2, and 3.

It is also common for manufacturers to try to save certain threads out of each frame; thus there may be five frames of yarns employed in the formation of a carpet, yet some of them may be incomplete. If one thread only is saved, it means increased profit; but sometimes a quarter of a frame is missing, sometimes half. If only a few threads are gone, the carpet is sold as if of the next superior quality; if half is gone, it is often sold as of so many frames and a half. But when well managed, a four-and-a-half frame carpet can often be sold as a five-frame carpet, and thus the manufacturer saves 130 threads throughout the entire length of the carpet. Such goods, with incomplete threads, do not wear so well as those with the full number of yarns; for wherever threads are left out, the carpet is thinner than where all the threads are present. See Figs. 1, 2, and 3.

The "gammot" being given to the weaver, he applies at the "yarn room" for such bobbins of worsted as he requires for the formation of the particular pattern; and these are selected from the "standard colours."

As it often happens that a dealer has not sufficient of a particular carpet to cover the floor of an entire room, new pieces have frequently to be made, which

shall exactly match with pieces previously woven. This necessitates the employment of a given number of colours, pieces of all of which are most carefully preserved. The composition of the dye with which each standard colour has been produced is carefully noted, and the utmost care is necessary when fresh yarns are dyed, in order that they exactly match the standard, for if ever so little out, the imperfectness of the match will be apparent, when large masses of carpet are united.

The endless chain of cards is now hung over that part of the Jacquard apparatus which is prepared to receive it, and the loom, having its yarns properly arranged, is set in motion; the loom now forms the fabric, and the Jacquard apparatus gives to it pattern.

The first seat of the Brussels carpet manufacture in England was Wilton, where it was introduced from Tournai in Belgium. It was established with us about a century since, or rather more. Kidderminster now supplies the great majority of such carpets, but they are also made in Bridgnorth, Halifax, Glasgow, and other places.

What are now termed Wilton carpets may be described as Brussels carpets with a velvet (instead of a looped) pile. They are made in exactly the same manner as Brussels carpets, only the wire over which the warp threads pass, in order to the formation of the looped surface of the Brussels carpet, is larger, and its end is flattened into a blade resembling that of a pocket-knife. The increased size of the wire makes bigger loops, and the knife blade cuts the loops as the

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 5 is three widths joined together.
Fig. 6 shows three strips of such a carpet joined together.

wire is drawn from the carpet. When made, this carpet is damped, and then passed over steam drums with the cut loops outwards, and thus the pile is raised to an even velvet-like surface.

There is a class of pattern which is not well adapted for the Wilton fabric, as such patterns involve the cutting of a double set of cards, and thus double the expense that is necessary to the production of a more suitable pattern. Such patterns are those which repeat by folding, as Figs. 6 and 7.

The cause of the unsuitability and expense of such patterns is this: the pile of every Wilton carpet points, more or less, in one direction, and thus when one strip of carpet points in one direction, and the next strip in the opposite, the joined carpet looks like a fresh rolled field of young grass. To obviate this, two strips, the one of which I may describe as left-handed, and the other as right-handed, have to be woven, in order that the pile in the juxtaposed strips may point in the same direction.

Carpets are always so shown by the seller, that the purchaser looks into the pile, for when seen in this manner they look better than when viewed along the pile.

Owing to the length of the pile of the Wilton carpet being greater than that of the loops of the Brussels,

Fig. 7 shows a particular kind of pattern which repeats by one strip running in one direction, and the next in the opposite direction. It is a class of pattern which is suitable for a Brussels carpet, but not for the Wilton fabric.

These figures are mere diagrammatic representations, for each width of carpet would consist of two hundred and sixty threads instead of twenty-five, as shown in our figures. This pattern would be woven with three full frames of yarn, and is therefore a perfect three-frame *Brussels*.

a yard of the former contains about one-fourth more yarn than a yard of the latter, and is proportionally more costly.

Following the process by which Brussels and Wilton carpets are produced, came a method of manufacture in which the Jacquard apparatus was dispensed with, and by which the size of the loom was materially decreased. The long frames in which the bobbins of yarn are arranged are situated behind the loom, as I have before said, and are about twice as long as the loom itself. When these are dispensed with, a loom only requires one-third the space that it does when these are attached.

This new method consists in printing a pattern upon the warp threads, while arranged in a parallel series ready for the loom, with such dyes as shall penetrate the substance of the yarns, and then in weaving these threads into a fabric.

In order that figures shall appear on the finished fabric of proportionate character, it is necessary that the pattern, as printed upon the warp threads, be much elongated, for it is only the upper portion of each loop that shows upon the surface of a carpet, while the loop itself requires a considerably larger amount of yarn in order for its formation.

By this process the "frames" of the Brussels loom are done away with, as the entire warp threads are wound upon one roller, or beam; and the Jacquard apparatus with its cards is also dispensed with.

This process of manufacture is, however, unsatisfactory. The figures which it produces are indistinct,

and have a "sheeny," or dazzling effect, for all the threads cannot be brought exactly into place, owing to little inequalities in their thickness; and unless the utmost exactness can be secured, carpets thus formed can never be pleasing.

The method of manufacture just described involves the cutting of a fresh set of blocks for every new pattern—one block for each colour, just as in any other process of printing; but the number of colours which it can employ is limited only by expense.

A Mr. Whytock, of Edinburgh, invented a process by which carpets could be formed of dyed warps without new blocks being cut for each fresh pattern; and by his method, what are termed "tapestry" and "velvet-pile" carpets are produced—the former having a surface of loops, as the Brussels, and the latter of cut loops, as the Wilton carpet.

This process, while most ingenious, is also most difficult to explain; but I will try to make the method understood.

The pattern fixed upon is handed to the "putter on," who makes the necessary rule-paper drawing; only in this instance the paper is not divided into squares, but into parallelograms, or oblongs. Fig. 9. This elongation of each stitch, like the elongation of the entire pattern in the last method of manufacture, is rendered necessary by the loop taking up a certain amount of thread for its formation, while only the top of the loop is visible on the surface.

The pattern, formed of elongated stitches, and thus itself elongated, being completed on the rule-paper, is

the roller, or by employing a roller having the width of three stitches, when one passage of the dye-trough will suffice. This process is continued till the entire drum of yarn is dyed, when it is removed, being now ready for the loom. Thus one thread of the warp has been formed.

I have said that one thread of the warp is thus dyed. More than that has, however, to be done; for if the first thread of the pattern was that which is dyed, we have not only a warp thread of this pattern produced, but perhaps a first thread of this one pattern for six, eight, or twelve warps, according as six, eight, or twelve hanks of yarn have been wound on the drum. Each hank forms a thread of one warp, and each warp makes some seven or eight pieces of carpet of thirty-five to forty yards in length, or from about 240 to 320 yards of carpet.

In like manner a second strip of the rule-paper is now taken and fresh white yarn is wound around the drum. It is then dyed in cross stripes according to the plan of this second strip of rule-paper, when it is removed, it being ready to form a second warp thread or a series of second warp threads. A third strip of rule-paper is taken, and a drum of yarn is dyed in accordance with it, and thus the third warp thread, or series of third warp threads, is formed, and so on; the process being repeated till a sufficiency (two hundred and eighteen) of threads have been dyed to form the entire warp, or a series of entire warps.

If the pattern repeats but once in the width of the

passed to other hands, and is by them cut vertically between each row of stitches. Fig. 10.

The patterns employed upon tapestry carpets generally repeat in either 648 or in 864 stitches, but various makers probably employ various lengths of pattern.

An enormous tin drum, having a circumference which measures exactly that of the amount of yarn necessary to form the 648 or 864 stitches, is divided by an index, which borders one end, into the number of stitches which the yarn on its circumference is to form; thus it may be divided into 648 equal parts, or, if larger, into 864. The threads upon the rule-paper strip, whether they be of the number of the divisions of the drum, or of such a number as will equally repeat in this number, are marked so as to correspond with the consecutive divisions of the drum. Upon this drum one layer (which may, however, consist of six, eight, or even twelve hanks of yarn, so large are the drums) of yarn is wound; the drum therefore, when covered with yarn, looks much like a monster cotton-reel, only it has no projecting rim, and carries but one layer of thread. Fig. 12.

Underneath the centre of this drum, and passing in the direction of its axis, is a small railroad, with its rails a few inches apart. On this run little wheeled troughs, in each of which is a roller having its external surface formed of felt—the roller being situated partly in and partly out of the trough, just like a common grindstone.

For the sake of convenience, these rollers are of

the roller, or by employing a roller having the width of three stitches, when one passage of the dye-trough will suffice. This process is continued till the entire drum of yarn is dyed, when it is removed, being now ready for the loom. Thus one thread of the warp has been formed.

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In like manner a second strip of the rule-paper is now taken and fresh white yarn is wound around the drum. It is then dyed in cross stripes according to the plan of this second strip of rule-paper, when it is removed, it being ready to form a second warp thread or a series of second warp threads. A third strip of rule-paper is taken, and a drum of yarn is dyed in accordance with it, and thus the third warp thread, or series of third warp threads, is formed, and so on; the process being repeated till a sufficiency (two hundred and eighteen) of threads have been dyed to form the entire warp, or a series of entire warps.

If the pattern repeats but once in the width of the

various widths; but this is only a means of saving labour, and the principle would be the same if each were only the width of one stitch, as shown in its elongated form on the rule-paper.

Into each trough dye is poured; and when the dyes necessary to the formation of the particular pattern have been prepared, one in each trough, the rule-paper is observed; and if the first stitch of the pattern is red, a trough of red dye is passed along the rails, and, owing to the situation of the drum of yarn, the upper part of a narrow felt roller in the red dye trough presses upwards upon the drum, and dyes a red stripe across it of the width of the one elongated red stitch.

The drum, which rotates on its axis, and the rotation of which is measured by an arm, and by its index, is now moved, so that the line already printed across the drum may just be escaped. Perhaps the next three stitches are green. In this case, a trough of green dye is placed on the rails, and run under the drum, so as to dye such a width of the drum as shall bear the yarn necessary for the formation of these green stitches. This will be accomplished by a felt roller, having the width of one elongated stitch, being passed three times under the drum, the drum having been moved on its axis the length of one stitch between each passage of

form one repeat of the pattern) arranged in proper order, but not woven together. The threads have been thus arranged or placed in proper positions by the "setters"; they are now ready for being wound upon the beam.

Fig. 14 shows a certain number of threads woven into fabric. The pattern no longer assumes an elongated form, for the length of the stitch is consumed in the formation of a loop, and the surface of the tapestry carpet consists only of loops, as does that also of the Brussels.

the roller, or by employing a roller having the width of three stitches, when one passage of the dye-trough will suffice. This process is continued till the entire drum of yarn is dyed, when it is removed, being now ready for the loom. Thus one thread of the warp has been formed.

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If the pattern repeats but once in the width of the

fabric (27 inches), the threads necessary to form a certain number of entire warps must be printed; thus the drum must be rewound with yarn and reprinted two hundred and eighteen times; but if the pattern repeats twice, or more times, in the width, then two, three, or more of the warp threads will be alike. In this case the one printing will produce two, three, or more threads of the one warp, for two, three, or more of the warp threads are alike. Thus, if six hanks of yarn were wound upon a drum, and it were printed to represent a thread of such a pattern as repeated six times in the width of the fabric, six threads of the one warp would be produced, as they are alike; whereas if the pattern had but one repeat in the width of the carpet, they would be used to furnish six distinct warps each with one thread. When the warp threads are printed, they are "steamed," in order that the dyes may the more fully enter the pores of the yarns, and then they are handed to the "setters," who place them in "setting frames," and arrange the various threads in the same relation to one another that the strips of the rule-paper held in relation to each other before they were separated by cutting. This having been done, the pattern becomes visible, although much elongated, and the warp resembles the printed warp of the last process which we have considered.

The warp being now "set," or arranged, it is wound upon a beam or roller, and transferred to the loom, where, by the common process of weaving, it becomes a fabric; only the fabric when produced is figured, for the warp threads had a pattern dyed upon them.

The advantage of this process is cheapness of production. It, like the last process, does away with the large frames of the Brussels loom, and, like it, effects a saving in ground space. It also resembles the last process in removing the necessity for the Jacquard apparatus with its cards, and in requiring only a simple loom for the weaving. But it has this great advantage over the last process—it does away with the costly blocks with which the yarn was previously dyed, while, like the last method, it can employ an unlimited number of colours, but this it does without materially increasing the cost of production.

The objections to the process are—that, owing to the warp threads being printed, the dyes run into one another and produce muddiness of effect, which becomes extreme when a dark comes next to a light colour. Also, owing to the difficulty of "setting" the warp threads with exactness, the pattern when woven has an irregular, broken, and most unsatisfactory appearance. To anyone having artistic taste, they can only be offensive, and it is also quite impracticable to make a small quantity of tapestry carpet.

"Tapestry" carpets have a looped surface like Brussels, but the loops are often cut, when a "velvet-pile" carpet is formed—the velvet pile bearing the same relation to tapestry that Wilton does to Brussels.

Tapestry and velvet-pile carpets have been chiefly made in Yorkshire, and the Crossleys have been their largest producers; but Kidderminster is now again commencing this manufacture—a fact which we cannot but regret, as the fabric when produced is of

such an unsatisfactory character; it is, however, cheap.

Carpets are also formed by a plain fabric being woven with the looped surface of Brussels, and by this being printed upon by blocks. This process is chiefly worked by the Messrs. Bright, of Rochdale, but it is as unsatisfactory in its results as the last method.

A most ingenious process by which beautiful carpeting is produced was devised by the Messrs. Templeton, of Glasgow, a few years since. It bears some analogy to the method by which tapestry carpets are produced, only the results achieved by Messrs. Templeton are as satisfactory, as those attained by the tapestry process are offensive.

The Templeton process produces what are termed patent Axminster carpets. In appearance they closely resemble the true knotted Axminsters, but they are cheaper, being wrought by a more mechanical method.

The pattern is first put "on lines," as in the former processes. Fig. 15. When complete, the rule-paper is cut *across* (not vertically as in the last case) between every thread. Fig. 16. These strips are now joined by their ends, and thus form a long continuous strip. But the right-hand end of the top strip will be joined to the right-hand end of the second, or next, strip; the left-hand end of the second to the left-hand end of the third strip, the right-hand end of the third to the right-hand end of the fourth, and so on, till all have been joined. See Fig. 16.

This strip will now be handed to a weaver, who places

it parallel with the warp threads in her simple loom (for the weavers are here girls) and weaves a striped fabric of the same pattern as this single strip; thus where there is one red stitch (or square) on this paper strip, she throws across a shuttle of red yarn, and where there is a black stitch (or square) on the paper, she throws a shuttle of black yarn: and if there are four stitches of green on the paper, she throws a shuttle of green yarn across four times, and so on, thus producing, by the agency of the hempen warp-threads, and the worsted weft, a fabric consisting of coloured cross stripes. Fig. 18.

This fabric being woven, it is cut into narrow vertical strips, each strip being from half to three-quarters of an inch in width, and each of such strips constitutes what is termed a chenille thread. See Fig. 18, top right-hand corner.

The chenille thread being formed, it is wound upon bobbins and is passed to another weaver (a man), who places a bobbin in a shuttle, and, having his loom prepared with simple threads, commences to weave, employing the chenille thread as a weft, and using the utmost care to keep the two cut edges of the chenille thread upwards; but in this he is aided by the nature of the thread which he employs, for a chenille thread is so woven that its edges have a tendency to rise in one direction.

It is apparent that, as the weaver now places his chenille thread just as the various strips of the rule-paper were situated before being cut apart (Figs. 15 and 16), the pattern which the rule-paper presented now makes its appearance in the chenille fabrics as it

Fig. 15.

Fig. 16.

Fig. 17.

Fig. 18.

Fig. 15 is a rule-paper drawing of a "chenille carpet," or "patent Axminster." *Fig. 16* is the same cut into strips. *Fig. 17* is these strips drawn out straight. All of these short

is produced; the cut edges of the chenille thread forming the chenille or velvet surface of the carpet.

Patent Axminster carpets may be very beautiful, and may bear a close resemblance to the gorgeous carpets of India and Persia; any number of colours may be employed in their production, and these colours, through being derived from separate yarns, do not run into one another and produce muddy and confusedness of effects. They are, however, more expensive than Wilton carpets, but less costly than the knotted carpets of Axminster.

By the patent Axminster process many hearthrugs are made. Others, termed thumb rugs, are formed by the true Axminster process, and others by the tapestry and velvet-pile methods.

All fabrics with a cut or velvet-pile surface made in England are, when woven, passed through a shearing machine, which trims the surface and gives evenness to the fabric. Persian, Indian, and Moorish carpets are not treated in this manner, hence they have a more artistic appearance.

I have now described the methods by which nearly all carpets are produced, but I have not called attention to the introduction of the power-loom.

Up to the time of the Exhibition of 1851, or nearly

strips should together form but one long strip: my pages being short, I am constrained to show it in four lengths, but these four lengths should be joined as shown by signs.

Fig. 18 shows a portion of this strip (the upper, or first part), woven as a striped fabric of the same pattern as the strip. At its right-hand upper corner this striped fabric is cut. By being cut into separate strips in the manner here shown, the chenille threads are formed that are again woven into a fabric.

so, all carpets were wrought either by the fingers or by the hand-loom, but about this time a great revolution in their mode of production set in, as steam-power was now applied to the working of the looms, and thus to the production of carpets.

The power-loom was the invention of a Mr. Bigelow, an American. With a hand-loom a man can weave in a day about seven yards of Brussels carpet, but by Mr. Bigelow's loom about twenty yards can be manufactured in the same time.

Here we have the commencement of a new system of weaving; and with marvellous rapidity steam-power superseded hand labour. But improvements were soon made upon Mr. Bigelow's invention, by which the action of the loom was materially quickened, and its working rendered more accurate: thus we have the looms of the present, which will weave from thirty-five to forty yards a day.

Brussels, Wilton, tapestry, and velvet-pile carpets, amongst the more elaborately figured fabrics, are now almost exclusively woven by the power-loom; but up to this time, the patent Axminster process has not yielded to the more modern method.

Certain improvements have recently been made in carpets which we cannot regard as bringing about any new kind of fabric, for they are rather attempts at doing away with sundry defects in what has hitherto existed. Thus the back of a common Brussels carpet, as well as of the tapestry fabric, is hard and harsh, and tends to cut the upper surface when in wear.

To obviate this difficulty in the case of Brussels

carpets, two methods have recently been adopted, the one resulting from a new mode of forming the backing of the carpet, by which a soft, instead of a hard back is obtained, and the other in covering the back with a soft cork-like substance. This latter invention is intended also to give protection from damp floors, and especially to increase the durability of the carpet when on stone or uneven boards. With the same object in view, thick felt has hitherto been placed under carpets when they are spread upon stone or an uneven surface, and it is the use of this felt, which the inventor of this cork-like backing seeks to save.

Pattern.—I now come to consider what class of pattern should be applied to carpets: and first I would notice, that whenever a great civilization has arisen and the arts have attained to high development, pictorial representations of flowers and landscapes have never occurred upon carpets: hence, by the unanimous consent of the cultivated of all ages, these have not been regarded as befitting decorations for a floor covering.

The finest models which we have to study at the present day are the carpets of Persia, India, and Morocco; in none of these do we find natural representations, but on the contrary a rich subdued, mingled beauty, which none can fail to admire. There is a neutrality of effect with fullness of colour, a subdued aspect with gorgeousness, enlivening qualities without obtrusiveness.

A carpet, as used with us, is a background on which furniture is to rest, and against which it is to

be seen to advantage; it must therefore be neutral in character and not unduly attractive. But neutrality does not imply muddiness of aspect; on the contrary, the most glowing colours may combine to produce a neutral tint, but if bright colours are employed with this object, they must be used in the smallest of masses, and be intermixed as much as possible,—many stitches of one colour never coming together.

This glowing neutrality is often that which is most desirable as a background, and it is that which the Persians so skilfully produce. The Indians often colour to a somewhat lower key than the Persians, yet they never obtain muddiness in their effects, though in some cases the patterns of India and Persia are identical, as I have already pointed out, and in these cases the colouring is also similar.

Moorish carpets generally contain more yellow than the rugs of Persia or India, but the yellow is often in a tertiary form, or in combination, as well as separate and pure. Thus, besides lemon and orange yellows, we have citrine and yellow greens; and I have seen Morocco carpets which, for beauty of colour and harmony, were unsurpassed by anything that I have ever seen in the way of woven fabrics.

There are certain forms and certain peculiarities of Oriental carpets which deserve at least passing notice; thus, the pine form, as it is termed, or Persian pine, is common on the carpets of Persia. Many will know the form better as occurring on Cashmere shawls. This shape is used as a carpet pattern, being simply and regularly distributed over the surface, and it is also to

be found in a much transmuted, or modified, state in many of the Eastern patterns. This pine form has to the Persian, and also to the Turk, a special significance, for it is the sacred cypress tree which they plant in their cemeteries; and on Persian earthen vessels I have traced every modification of form, from that of the tree as naturally drawn, to the extremely conventional shape known as the Persian pine.

Many Oriental rugs have patterns which point in one particular direction—to one end of the rug. All such rugs are prayer carpets. When the rug is set towards Mecca, the devotee prostrates himself upon it and performs his devotions; but those carpets which are made as floor or ottoman covers, never have such patterns applied to them as point in one particular direction. Some are only decorated with the pine form, so as to remind those for whom they are made of their dead.

It is curious to notice how both the Persians and the Indians produce, as it were, many patterns out of one design, by employing various methods of colour. If their patterns are attentively considered, it will be found that many of them contain star-like or flower-like ornaments, which are so situated in relation to one another as to form squares. By making all of these flowers light in one case, and dark in another, great diversity of effect is produced. In some instances, however, certain of the flowers are made dark and others light, and changes of this character are brought about in the most ingenious manner and with such consummate skill, that we have to look attentively, in

order to discover that the whole of the effects produced result from modifications of the one pattern.

There are many reasons why small patterns founded on a geometrical basis, such as the Persians, Indians, and Moors use, are preferable to large and naturalistic treatments of flowers and landscapes.

1st. A floor is an architectural and not a natural surface. It should therefore bear upon it ornament suited to its nature, and such as gives to it a proper place in relation to other architectural members.

2nd. Ornaments, flowers, or whatever has a pictorial treatment, is drawn in perspective, and being in perspective, it can only be seen correctly from one part of a room. Whatever is already in perspective, and is yet so seen as to suffer a second foreshortening, is unsatisfactory.

3rd. Every pictorial composition should be of such a nature that all its parts are necessary to completeness, and that it can only be satisfactory when seen as a whole. Small patterns which repeat many times, suffer little through being in part hidden by furniture, but pictorial patterns suffer much.

4th. As a floor is a flat surface, the object of the ornamentist should therefore be to make the floor look as beautiful as possible as a background, without destroying its proper qualities, or apparently disturbing its welcome flatness of surface.

We have seen that the patterns which Oriental carpets present never point in any one direction unless there is a special, a religious reason for their so doing. If we consider the teachings of nature, we shall perceive that the Eastern nations are right in not letting

the patterns point in one particular direction. If we wander over a moor, the only plants that we can walk upon are those which are extremely short, and which nestle in the moss-like grass. These we see from above, and these are the ornaments of nature's carpet. But as we see them, they all send out leaves and flowers from a common centre, and are star-like, or radiating ornaments. Not one points in any particular direction.

If we view a tree or a shrub from the side—anything that is large enough to be seen against the sky as a background—it points upwards; but as thus seen, it is the ornament of a vertical surface, and is a type of wall ornaments, and such may well point in one direction; but floor patterns should always point in four or more ways.

DYEING.

By T. Sims (Mayfield Print Works).

The art of dyeing consists in the impregnation of the material with certain foreign substances or colouring matters, including all bodies, whether of animal, vegetable, or mineral origin, which are used to impart colour to various materials.

In this article I shall only treat of dyeing in its application to organic fibres.

To produce bright and delicate colours, it is necessary that the fibre should be freed, as completely as possible, from natural colouring matters and all other impurities, before it is subjected to the process of dyeing.

From ancient records it appears that certain methods of dyeing have been known and practised from time immemorial. The Tyrians were celebrated for their fine purple dye, said to have been obtained from two different kinds of shell-fish. The ancient Indians and Egyptians also successfully practised the art, and were even able to produce coloured patterns upon woollen and cotton fabrics, by processes analogous to those now in use.

Vegetable and animal fibres differ considerably in their power of attracting colouring matters; the latter

possessing this property to a much greater extent than the former.

Vegetable fibres generally require the aid of some substance to effect the adhesion to them of colouring matters, whilst animal fibres, for the most part, will retain the colouring matters without it. The term "mordant" is applied to these intermediate substances. Bancroft has grouped colouring matters under two classes, the first including those which can be fixed upon the fibre without the intervention of an earthy or mineral basis, e. g. indigo, safflower, &c.; and the second, those which are incapable of fixation, except through the mediation of some such basis, e. g. madder, cochineal, &c. To the first class he gave the name of "substantive," and to the second that of "adjective" colours.

In the process of dyeing, the goods, either mordanted or not, according to the nature of the fibre or colouring matter, are generally immersed in a solution or decoction of the colouring matter, which is then gradually heated to the boiling point. If, under these circumstances, the matter is attracted to the fibre and rendered insoluble in water, the colour will be retained; but if otherwise, it will be removed when the goods are placed in contact with water. Hence the term "fast" is often given to those colours which resist the domestic operations of washing, without material alteration in the appearance of the goods. The main object of the dyer is to effect the fixation of the colouring matters as completely as possible, though the degree of fastness required must necessarily vary according to circum-

stances. The permanence of colours, i.e. the power of resisting the destructive agency of the air and light, is also a matter of importance, for colouring matters differ much in this respect.

As regards the theory of dyeing, two different ones have been advanced to explain the mode in which colouring matters become attached to organic fibres. The one attributes the adhesion to mechanical, rather than chemical agency; the other considers that a union of a chemical nature is effected between the fibre and the colouring matter or mordant. The former was enunciated by Hellot, who held the opinion that colouring particles are admitted into the fibres through pores or cavities, which, under the influence of heat, open to receive them, and are closed again when cold, the colouring particles being covered with a kind of cement, left in the pores by the salts used in their preparation. According to Le Pileur d'Apligny, who supported the same theory, the different behaviour of various fibres towards the same colouring matter arises from the size and number of the pores being greater in one case than in another. The chemical theory was held by Bergman, Macquer, and other chemists, all of whom considered that the fibre itself possesses a chemical attraction for the colouring matter or mordant, and that this takes place rather on the surface of the fibre than within its pores. This theory was generally held until 1843, when the late Mr. Crum revived, to a certain extent, the mechanical idea. In 1846 M. Persoz published his 'Traité de l'Impression des Tissus,' in which he controverted the opinions of Mr. Crum. In 1863

Mr. Crum brought forward fresh illustrations in support of his views,* and answered most of the objections that had been raised against them, explaining so well many of the phenomena connected with the fixation of colouring matters upon cotton goods, that his opinions are generally recognized at the present time. He discarded the notion of a chemical union, considering that the attraction of the fibre for colouring matters, which he admitted does exist in some cases, is analogous to the force which enables charcoal to absorb gases, and to attract solid substances from their aqueous solutions. Mr. Crum thought that the walls of the fibre must be porous, since organic membranes allow of the passage through them of certain substances in a state of solution, although no lateral perforations can be detected, even with the aid of the most powerful microscopes. Hence he concluded that substances applied to cotton as dyes, or for the purpose of attracting dyes, become fixed in the fibre in one or other of the two following ways:

1. They are attracted, and precipitated from their solutions by the pores of the cotton.

2. They enter these pores in combination with an acid, or other solvent, and in a state of solution, and are there fixed, not by the effect of porosity, but by the subsequent removal of their solvent, or by other means which render them insoluble in water.

The successful development of dyeing processes has been accomplished by a thorough acquaintance with the chemical properties of colouring matters. Dyeing

* 'Chem. Jour.,' xvi. 1.

is essentially a chemical art, and its numerous processes consist in the application of chemical principles.

Within the last ten or fifteen years the art of dyeing has received enormous impetus, from the discovery of many new colouring matters produced by artificial means; notably the so-called aniline colours, which on account of their brilliancy, variety of shade, and the ease with which they can be applied, have superseded, to a great extent, the use of many of the older dye stuffs; and more recently by one of the most important chemical discoveries of the present age, viz. the artificial preparation of alizarine, which has wrought quite a revolution in the dyeing of printed calicoes.

Dyeing is most intimately associated with calico printing, which may be looked upon as a preliminary operation, to be followed by others which have, more or less, the character of dyeing. The great object of printing is the production of a dyed fabric, not necessarily of one uniform colour throughout, but impressed with a figure or pattern consisting of one or more colours. The two chief modes in which printing is performed are called block and cylinder printing. In block printing, the colouring matter or mordant is applied by means of wooden blocks, worked by hand. The size varies according to the pattern, which is drawn and cut in relief upon the wood, or formed by the insertion of small slips of flattened copper wire, the interstices being filled up with felt. Each block is furnished with pin points at the corners, to enable the printer to place it in its proper

position upon the cloth. The mordants, properly thickened to prevent their spreading beyond the limits of the design, are spread upon a fine woollen cloth, stretched tightly over a wooden hoop or drum, called the "sieve," which is rendered elastic by floating it upon some size or paste in a shallow tub. The printer charges his block by pressing it gently upon the sieve, and then transfers the adhering colour to the cloth spread upon the printing table, the top of which consists of a large flag resting firmly upon an iron framework; its surface, which must be perfectly smooth and horizontal, is covered with a blanket, to give it elasticity. The pieces to be printed are first smoothed by calendering, then wound on a roller, from which they are again unwound and drawn over the table as the printer proceeds with his work. By repeated applications of the block the pattern is produced in one colour only, and therefore, if the design consist of more than one colour, the same number of different blockings will be required. By modifying the construction of the sieve, it is, however, easy to apply several colours at once by means of one and the same block. The sieve called the "Toby" consists of a block of wood in which hollow spaces are scooped, corresponding in number, size, and position with the colours in the design, each space corresponding to any particular colour being connected by tubes with a small reservoir of that colour; while a bottle of the same is inverted over that in the reservoir, to keep up the supply. The surface of the sieve is covered with a woollen cloth, through which the colours penetrate,

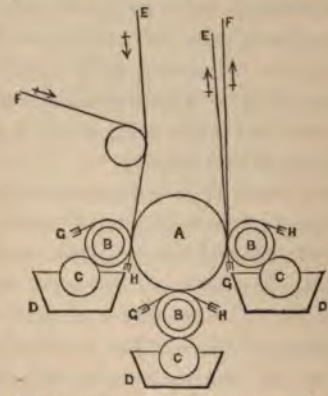
and to prevent them from running together and mixing, a piece of string is cemented to the cloth along the boundary of the spaces. The block is furnished with two iron pegs which slide down guiding grooves at the side of the sieve, and so cause the block to be always dipped in the same place. Other forms of sieve are used for special purposes, but I have not space to describe them. The printer, after completing each table length of his pattern, draws this portion of his piece over a roller, and a number of rails fixed to the ceiling of the room, in order to dry the colours.

Various machines have been constructed by which block printing can be mechanically performed. The most important of these is the Perrotine, which, though frequently found in French print works, has not come into common use in this country.

Of the many mechanical inventions introduced from time to time into the manufacture of printed and dyed fabrics, that of the cylinder printing machine is the most important; for by it we can print one or more colours upon the cloth at one operation, with wonderful accuracy and speed. The thickened mordants are applied, in the first instance, to engraved copper cylinders or "rollers," from which they are transferred immediately to the cloth by pressure and rotation. A separate roller is required for each colour, and therefore a pattern consisting of more than one colour is dissected, and the various parts engraved upon different rollers, each of which must be a few inches longer than the width of the cloth to be printed. The pattern is reconstructed or produced upon the cloth by adjusting

these rollers in the machine, so that each will apply its colour in the proper place.

The cylinder printing machine consists of two similar cast-iron frames, fixed in a vertical position, at a distance of from three to four feet apart. These frames support the axles of the copper rollers, also those of the pressure bowl, round which the cloth is made to travel, and against which it is pressed by the copper rollers. The annexed diagram will enable the reader to acquire a general idea of this machine and its mode



of action. A represents the pressure bowl, covered with several folds of woollen cloth to give it elasticity; around this travels an endless blanket, or sheet of mackintosh E, forming a guide for the cloth F, which passes along with it between the bowl A and the engraved rollers B. The latter are on strong iron mandrils, the ends of which rest in bearings supported by projecting arms of the end frames of the machine.

These bearings are placed in slots, and have attached to them a system of screws, levers, and weights, by which the rollers can be forcibly pressed against the bowl. The rollers revolve by toothed wheels, one being fixed to one end of each mandril, and all working in the teeth of a large spur wheel, in connection with the main driving shaft. The friction of these rollers against the pressure bowl causes the latter to turn, and to draw the blanket E along with the cloth F through the machine. The rollers C dip into the thickened colours in the troughs D, and revolve by small wheels connecting them with the mandril ends; they thus acquire a coating of colour, a portion of which they impart to the engraved rollers. As the colour is applied to the entire surface of the engraved rollers, the superfluous colour adhering to the plain or unengraved portions is removed before the rollers come into contact with the cloth, by fixing a thin metallic plate, called the "cleaning doctor," with its sharpened edge in contact with the engraved surface, so that the colour scraped off shall fall back into the trough. Each roller is provided with a cleaning doctor G, and also with a similar scraper H, called the "lint doctor," one object of which is to remove any loose threads that may have become detached from the cloth in the act of printing, and prevent them from entering the colour trough.

The cloth, after leaving the printing machine, is carried forward with the blanket to the drying chamber, where they part company, the blanket returning to the machine, and the cloth passing onwards, in close

proximity to a long range of steam chests until the colours are perfectly dry.

The pieces to be printed are sewed together end to end, and then wound upon wooden rollers, supported on brackets behind the printing machine, and the pieces are unwound and drawn through the machine without stoppage.

The processes for the application and fixation of colouring matters are so infinitely numerous, and differ so much according to the nature of the tissue and the colouring matters, that I can only notice a few of the most important.

Commercial indigo is a dark blue substance, prepared by macerating the leaves of various plants in water until fermentation takes place, the yellow-coloured solution thus obtained depositing a blue precipitate in contact with the air, which, when washed and dried, constitutes the commercial article. The plants which yield the largest amount of indigo belong to the genus *Indigofera*, and are natives of tropical countries. One European plant is known to yield indigo, viz. the *Isatis tinctoria*, or dyers' woad, which has long been cultivated in this country, and is said to have been employed by the ancient Britons to dye their skins. Commercial indigo should contain from 50 to 60 per cent. of a blue colouring principle called indigotine, or indigo blue, which is insoluble in water, dilute acids, and alkalies; but when placed in contact with an alkaline solution and a deoxidizing agent, it undergoes a remarkable change. Water is decomposed, and its hydrogen combines with the indigo blue

forming indigogen, or indigo white, which is a colourless substance, differing from indigo blue by containing more hydrogen. Indigo white is insoluble in water and acids, but easily dissolved by alkalies; the solution, however, absorbs oxygen from the air and deposits indigo blue.

The process of indigo dyeing, technically called "dipping," consists in immersing the goods in a solution of indigo white, and then exposing them to the air, in order to reproduce the indigo blue within the fibre by oxidation. Various deoxidizing agents and alkaline solutions are used in the preparation of the solution of white indigo. For cotton goods, ferrous sulphate, or copperas, and slaked lime are introduced along with the indigo, previously ground with water to a smooth paste, into large stone cisterns called "vats," nearly filled with water; the mixture is well stirred and then allowed to settle. The action of the lime on the solution of ferrous sulphate forms ferrous hydrate; this takes up oxygen from the water and is converted into ferric hydrate, and the liberated hydrogen unites with the indigo blue, forming indigo white, which dissolves in the excess of lime, leaving a yellow solution; sulphate of lime being deposited at the bottom of the vat. The operation of dipping is thus performed. As the cloth will not absorb sufficient colouring matter by one immersion in the indigo vat, it is usual to employ several vats, into which the pieces are dipped in succession; the first vat contains milk of lime, and the others are charged with indigo solution, of gradually increasing strength from the first to the

last. To expose the cloth thoroughly to the solution and uniformly dye it, it is usually stretched by hooking it backwards and forwards upon the upper and lower bars of wooden frames which just fit the vats. Each frame will hold from 50 to 60 yards of cloth, and is lowered into or raised out of the vats by a rope and pulley attached to the roof of the building. The frames are first lowered into the lime vat, in order thoroughly to wet the cloth so that it will absorb the indigo solution with ease and regularity, and to detach minute air bubbles which adhere to its surface. The frame is then removed, allowed to drain, and introduced into the first indigo vat. After remaining here for a few minutes it is withdrawn, exposed to the air, allowed to drain, and then passed on to the next vat, and so on until it reaches the last. If the colour is now sufficiently intense, the pieces are unhooked, and washed first in a cistern containing water, and then in another containing dilute sulphuric acid, in order to remove the lime and oxide of iron adhering to the fibre. After washing again, the pieces are squeezed between rollers and dried. Smaller vats are used for dyeing cotton yarn, and the liquor is generally heated by steam pipes. The skeins of cotton are placed round wooden poles resting upon the sides, so that the lower part of each skein dips into the liquor, whilst the upper part is exposed to the air. The cotton is turned round from time to time, until it has assumed the required depth of colour.

Indigo is applied to woollen fabrics also in the state of white indigo. The vats for woollen dyeing are pre-

pared or "set" in various ways, but in all cases there is added to the indigo some organic substance, such as woad, madder, molasses, bran, &c., which is prone to undergo fermentation when macerated in water and subjected to a slightly elevated temperature. The hydrogen evolved during the fermentation transforms the indigo blue into indigo white, which is dissolved by the addition to the vats of some alkali, or alkaline carbonate. The woad plant formerly used as a source of indigo blue is now seldom used on account of its colouring matter, but chiefly for exciting fermentation in the indigo vat.

China blue dipping is a peculiar process, in which indigo is printed in designs and subsequently fixed upon the cloth. The printing colour is composed of a mixture of very finely ground indigo with ferrous sulphate or acetate, and orpiment, thickened with gum. The process consists in drawing the pieces by rollers fixed on a suitable framework forward and backward several times, first through a vat containing milk of lime, and then in a similar way through one containing a solution of ferrous sulphate; the operation being repeated alternately, first through one and then the other, until the fixation of the indigo is complete. The process depends: 1st, upon the conversion of the indigo blue into indigo white by the ferrous hydrate precipitated upon the cloth; 2nd, the solution of the indigo white by the excess of lime; 3rd, the attraction of the white indigo and its removal from solution by the fibre; and 4th, the reconversion of the indigo white into indigo blue by exposure to the oxidizing

influence of the air. After removal from the vats, the pieces are washed in water, then in dilute sulphuric acid, to remove the oxide of iron, and finally treated with a warm solution of soap.

Cotton fabrics are also dyed with indigo by printing white indigo upon the cloth. Two different colours are used for this purpose; the first called pencil blue, in which the white indigo is held in solution by some alkali; and the second, called precipitate or fast blue, in which the white indigo is in the insoluble state. In the first case the white indigo is withdrawn from its solution by the attraction of the fibre, and converted into indigo blue by exposure to the air, and rinsing in water: but in the second, the cloth, after printing, is passed through a solution of an alkaline carbonate, whereby the white indigo is rendered soluble, and then being attracted and withdrawn from solution by the fibre, is afterwards oxidized as before.

When indigo is treated with concentrated sulphuric acid, several compounds are formed, which, on account of their solubility, can be directly used in dyeing. The indigo, however, has by this treatment undergone a complete change, and no process is known by which the blue can be restored to its original condition. These derivatives of indigo have no affinity for cotton fibres, but are frequently used for dyeing wool and silk.

The class of colouring matters called pigments have no appropriate solvents, and therefore cannot be made to enter into the fibre; but as several of these pigments possess such extraordinary brilliancy

and permanence, many attempts have been made to attach them to cloth by mechanical means. The most successful method consists in mixing the pigments, previously ground to an impalpable paste or powder, with white of egg or albumen, and printing the mixture upon the cloth. The goods are then hung in a suitable chamber into which steam is introduced, by which the albumen is coagulated and rendered insoluble. The colouring matter enclosed in the coagulum is thus mechanically attached to the surface of the fibre. The pigments most commonly used are ultramarine, hydrate of chromium ("vert guignet"), the yellow and orange chromates of lead; oxide of zinc ("zinc white"), and lampblack. The application of pigments in this way has enormously increased within the last few years, chiefly owing to the manufacture on the large scale of egg albumen, and the introduction of a cheaper, though inferior, kind of albumen, obtained by drying blood serum. The degree of fastness of pigment colours fixed by albumen is very considerable, and they will resist a long boiling in soap and water, provided that no violent friction be applied.

All insoluble colouring matters, when reduced to a fine powder, can be fixed upon woven fabrics by the process just described; but many of the insoluble mineral colouring matters can be more completely fixed by causing their deposition within the fibres by chemical means. In this mode of dyeing, the colouring matters are the result of the chemical decomposition of certain soluble metallic salts, with which the tissue has been impregnated. These decompositions are brought

about in different ways. Thus calico is dyed buff by the deposition within its fibres of the insoluble ferric hydrate. This may be effected by impregnating it with a solution of ferrous acetate; but since the fibre itself has not the power of separating the ferrous hydrate from its solvent, the solution of ferrous acetate is allowed to dry upon the cloth, which is then exposed to a moist and warm atmosphere; acetic acid escapes, oxygen is absorbed, and insoluble ferric hydrate is left, fixed within the fibre, so that it cannot be removed by washing. In cases where this spontaneous decomposition cannot occur, the precipitation of the insoluble colouring matter is effected in other ways. Thus iron buff may be produced by first saturating the cloth with a solution of ferrous sulphate, and then passing it through milk of lime, or other alkaline solution. Instead of passing the cloth through two solutions consecutively, it is frequently advantageous to employ a more complicated method. Thus we might apply the yellow chromate of lead by passing the cloth in succession through solutions of acetate or nitrate of lead and bichromate of potash; but it is more desirable, for several reasons, first to impregnate it with the soluble lead salt, then to precipitate the lead within the fibre as insoluble sulphate or carbonate by a passage through a solution of an alkaline sulphate or carbonate, and finally to convert the latter into chromate of lead by passing the cloth through a solution of bichromate of potash. If now the cloth, dyed yellow with chromate of lead, be passed through boiling milk of lime, a portion of the chromic acid is abstracted by the lime,

as soluble chromate of lime, whilst there remains fixed within the fibre a basic chromate of lead of a fine orange colour.

When it is desired to impart the colour to the entire surface of the cloth, one at least of the solutions is often applied by the "padding machine," which consists of a trough containing the solution, over which is fixed a pair of cylinders or "bowls" revolving in contact with one another. The cloth is made to pass, first through the solution, and then between the bowls; thus preventing unnecessary waste of the solutions and ensuring their uniform application to the tissue. Or one of the solutions may be thickened with some amylaceous or other substance, and printed upon the cloth by a block, or a copper roller, the entire surface of which is covered with a fine pin engraving. The printed cloth is then passed through the other solutions necessary for the production of the colour, which are conveniently placed in cisterns provided with rollers at the top and bottom, over and under which the cloth is drawn continuously. It is evident, that by the use of proper blocks or engraved rollers a pattern or design may be produced.

With the exception of indigo, safflower, and the aniline dyes, there are scarcely any dye stuffs, the colouring matter of which can be fixed without the aid of a mordant.

The essential requirements in a mordant are: 1st, that it must possess the property of combining, and forming an insoluble compound with the colouring matter; and 2nd, that it must itself be capable of

fixation within the fibre. Several metallic oxides, especially alumina, ferric oxide, and stannic oxide, form insoluble coloured compounds, termed "lakes," with the colouring principles of the organic dye stuffs; and as these oxides can be precipitated, or deposited within the fibre in various ways, they are used by the dyer as mordants.

The precipitation and fixation of mordants forms a most important process in the operations of dyeing.

In order to fix a mordant within the fibres of any tissue, it is necessary that it should be applied in a state of solution, as the walls of the fibre are impervious to solids. Hence the soluble salts, from which the metallic oxides can be obtained by precipitation or decomposition, are those employed for this purpose. The term "mordant" is both applied to the metallic oxides themselves, and to the solutions from which they are obtained.

Acetic acid is the usual solvent employed for the aluminium and iron mordants, since the acetates of these metals are easily decomposed by heat, with the escape of the volatile acetic acid, and deposition of the insoluble oxide. When other solvents are used, the oxides are precipitated within the fibre by passing the cloth through some solution which will cause the separation of the oxide. Thus fabrics impregnated with solutions of aluminate of potash, ferrous sulphate or chloride, or stannate of soda, are severally passed through solutions of sal-ammoniac, caustic soda, or sulphuric acid.

Occasionally advantage is taken of the power which

the fibre itself possesses of decomposing metallic solutions. Thus cotton fibres by immersion in alkaline solutions of monoxide of lead separate from them the oxide, and cotton fabrics so prepared can be dyed yellow or orange with bichromate of potash in the way already described. Again, if cotton fabrics be immersed for some time in solutions of the so-called oxychlorides of aluminium or iron, and then be placed in water, it is found that they retain considerable quantities of ferric or aluminium hydrate as the case may be.

Mordants may be applied to cloth, together with or after the colouring matter; and may also be applied to the entire surface or only to certain parts of the fabric. But in calico printing the thickened mordants are usually applied before the colouring matter, and the choice of suitable thickenings is important. The substances generally used are flour, starch, and natural or artificial gums.

The colours which can be produced from any particular dye stuff vary according to the nature, and their intensity varies according to the degree of concentration of the mordants employed.

From what has been already stated respecting the fixation of mordants, it will be evident that this takes place chiefly in the treatment called "ageing," which consists either in hanging the goods up for several days in a room where the atmosphere is kept well ventilated, warm, and moist, or by passing them slowly through a chamber, the air in which is heated and nearly saturated with moisture by steam pipes and

jets of steam. The evolution of large quantities of acetic acid from goods which have been mordanted with acetates, may be readily noticed.

As the precipitation of the mordants during the process of ageing is never complete, it is necessary to remove the undecomposed or superfluous mordant from the cloth before dyeing, as the excess, if allowed to remain, would cause a waste of dye stuff. A simple washing in water would do this; but in the case of printed goods, where the mordants have only been applied to parts of the cloth, the superfluous mordant, as it dissolved in the water, would spread over the unprinted parts of the surface, and cause the attraction of colouring matter in dyeing, and consequently an obliteration of the design or pattern; hence it is necessary to wash the pieces from the excess of mordant in some solution, which will prevent its becoming again attached to the fibre. Formerly cowdung mixed with hot water was used for this purpose, but of late years it has been almost entirely superseded by solutions of phosphate, silicate, or arseniate of soda, though the process still retains the name of "dunging." The action of cowdung is probably chiefly mechanical, and due to the surface attraction exerted by the particles of organic fibre which it contains; but when the substitutes for cowdung are employed, the superfluous mordant is precipitated in an insoluble state directly it leaves the cloth, and rendered incapable of re-entering the fibre.

Another object to be attained in the process of dunging printed goods is the removal of the sub-

stances used for thickening the mordants, and it is necessary that this should be most effectively performed.

The process of dunging is performed continuously, by passing the pieces sewed together end to end, 1st, through one or two large cisterns with rollers at the top and bottom, over and under which the cloth is made to travel, extended to its full width; and 2nd, through a series of vessels resembling "dye becks," through which the pieces are drawn spirally in a rope-like form. These cisterns and becks are filled with a very dilute solution of the dunging salt, which is heated by steam pipes to a temperature of from 120° to 180° Fahr. The cloth, after dunging, is drawn once or twice through a washing machine, and is then ready for dyeing.

The actual process of dyeing consists in exposing the mordanted cloth to a decoction of the dye stuff or a solution of the colouring matter in vessels called "dye becks." The ordinary form of dye beck is an oblong cistern of iron or wood, over which is supported a revolving winch or reel. Each dye beck is furnished with a perforated steam pipe, crossing it from end to end at a few inches from the bottom, and also with a perforated diaphragm, fixed across the beck just above the steam pipe, thus dividing the beck into two parts. The dunged pieces are generally detached, two in a length, after washing, and seven or eight of these lengths are placed in a row across the dye beck, into which is run the requisite quantity of water; the end pieces of each being then tied together,

so as to encircle the winch, steam pipe, and diaphragm, and the bulk of the cloth being pushed down into the front part of the beck, the dye stuff is introduced. The winch is then set in gear with the driving shaft, and the steam turned on. The cloth is thus drawn by the revolving winch through the dye bath, and deposited again at the front in a continuous manner throughout the period of dyeing.

The apparatus just described is that usually employed by calico printers, by whom the dyeing of cotton goods is chiefly performed; but for other purposes large copper boilers, heated by steam, or a fire underneath, are often employed.

Another method consists in the topical application to the fabric of the colouring matter. For this purpose the mordant is either first applied to, or fixed within the fibre by suitable means, and then the colouring matter, mixed with some thickening substance, is printed upon the prepared cloth; or the mordant and colouring matter are both mixed together, and the thickened mixture printed as before. In either case the goods are afterwards exposed to the action of steam, by hanging them up, and enclosing them in an iron box or chamber, into which steam is admitted. The mordant, if not previously fixed in the fibre, soon becomes fixed under the influence of the steam, which also effects its combination with the colouring matter, and the production of an insoluble lake within the fibre. Colours applied in this way are called "steam colours."

I will now briefly describe the principal dye stuffs,

and the methods by which their colouring matters are made available.

The colours which the dyer has to produce are of infinite variety. The simple colours, blue, red, and yellow, are obtained by immersing the goods in a bath of the particular dye required. The intermediate or compound colours are generally the result of the admixture of two or more dye stuffs.

The principal blue colouring matters are indigo, ultramarine, Prussian blue, and the various aniline blues.

Indigo and ultramarine are applied by the methods already described.

Prussian blue is applied to cotton, woollen, and silk goods, by impregnating them first with ferric oxide, and then immersing in a slightly acid solution of yellow prussiate of potash. Or it may be produced by the topical application to the cloth of a thickened mixture containing yellow or red prussiate of potash, tartaric acid, and prussiate of tin, though the colour is brighter and more intense if the cloth be previously mordanted with stannic oxide: the blue is developed by steaming, and then exposing the goods to the air.

The aniline blues are chiefly used in woollen and silk dyeing, and are attracted from their solutions by the fibre without the aid of a mordant.

The chief red colouring matters are safflower, cochineal, brazil-wood, barwood, madder, and the aniline red dyes.

Safflower is a red colouring matter, obtained from the flowers of the *Carthamus tinctorius* by treating

them with water. This is first dissolved in a weak alkaline solution, and then precipitated by an acid immediately before dyeing; and in this condition it attaches itself to organic fibres without the aid of a mordant. Safflower colours are very fugitive, and in consequence have been superseded by the more permanent aniline dyes. It is, however, sometimes used for dyeing silk, to which it imparts a very delicate pink.

Cochineal occurs in commerce in the form of small seed-like grains, which are the dried bodies of the females of a certain genus of insects called cocus. The best qualities are imported from Central America. It contains about 50 per cent. of a colouring matter called carminic acid, which can be easily extracted by boiling water, and is used for dyeing various shades of pink, scarlet, and crimson, principally in woollen goods, and the colours are remarkable for their brilliancy, fastness, and permanence. To obtain scarlet, a tin mordant (nitromuriate of tin) is added to the dye bath, while the addition of alum alters the shade to crimson. Cochineal is not used for dyeing cotton goods, but a fine red or scarlet may be produced upon calico, previously mordanted with stannic oxide, by printing a colour containing cochineal extract, chloride or acetate of tin, and oxalic acid, thickened with starch, and then steaming.

Under brazil-wood may be included the woods of various leguminous trees, of the order *Cæsalpina*, which are known in commerce under the names of lima, sapan, and peachwood. Their colouring prin-

ciple, called brazilein, is soluble in water, and a decoction, prepared by boiling the rasped woods, is used for dyeing reds on woollen and cotton goods; the former are mordanted by immersion in a solution of alum and cream of tartar, then rinsed in water, and placed in the dye bath, which is kept at a lukewarm heat. The finest shades are produced in a bath which has previously been partially exhausted. Cotton goods are prepared, before dyeing, by immersion in a decoction of sumach, or gall nuts, or a solution of tannic acid, and then in one of alum, or chloride of tin. Topical steam colours for printing are prepared from the extracts of these woods by the addition of alum and chlorate of potash, thickening with starch. The colours obtained from these woods are very fugitive, and gradually fade by exposure to sunlight.

Barwood, cam and sandal wood contain a red colouring matter only slightly soluble in water, so that, in dyeing, the rasped wood itself is put into the dye bath, and the goods are introduced into the boiling liquor. The same mordants are used as for brazilwood, but the colours produced are more permanent.

Madder is the most important of all dye stuffs, indigo only excepted, and is capable of yielding shades of greater variety and permanence than any other colouring matter. It is the dried root of the *Rubia tinctorium*, an herbaceous plant extensively cultivated in the Levant, France, Holland, and other countries. It is almost exclusively used for dyeing cotton goods, and though generally classed among red colouring matters, it is used for the production of

various other colours upon calico. Cotton fibres have no attraction for madder without the assistance of mordants; but as the aluminous and iron mordants combine with the colouring matter of madder, forming different coloured insoluble lakes, the process of madder dyeing consists in placing the cloth, prepared with either of these mordants or a mixture of the two, in a dye beck containing water and the ground madder. The temperature is gradually raised to about 180° Fahr. by steam, and the goods are moved about in the liquor, until the mordants are saturated with colour, the process generally taking from two to three hours. After dyeing, the adhering madder is removed by passing the pieces through a washing machine. Even after this the colours appear dull, and the unmordanted parts of the cloth, or those which are intended to remain white, are also stained. To remedy these defects the pieces are boiled in a weak solution of soap, by which the colours are brightened, and the whites cleared, by the removal of a reddish-brown colouring matter which attaches itself to the surface of the cloth during the dyeing.

The ordinary madder reds are produced by the use of acetate of alumina ("red liquor"), as the mordant; black and purples by acetate of iron ("iron liquor"); and chocolates by a mixture of red and iron liquor.

Turkey red is a madder colour much valued on account of its brilliancy, fastness, and permanence. It is produced upon cotton fabrics by a tedious process, of which the following are the main points: *1. Oiling,* or saturation of the cloth with an emulsion

made by mixing gallipoli oil with a solution of pearlash, and then drying the oiled cloth by exposure to the air, or by passing it over a hot flue; this operation is repeated several times. The excess of oil is removed by steeping in a dilute solution of pearlash. 2. Galling, which consists in passing the cloth through a decoction of galls and then drying. 3. Mordanting, or impregnation of the cloth with a solution of alum or acetate of alumina. 4. Cleansing, or washing in hot water with cowdung and chalk. 5. Dyeing. 6. Clearing or boiling the dyed goods in a weak solution of soap. 7. Brightening of the colour by boiling the cloth under pressure with a weak solution of stannous chloride.

The colouring matters of madder have formed the subjects of investigation by many chemists. It appears that only two of these, viz. alizarine and purpurine, are concerned in the production of the ordinary madder colours. The former by itself is capable of yielding all the ordinary madder colours, and the colours so obtained possess equal brilliancy, fastness, and permanence to those obtained from madder; the latter dyes mordanted cloth with facility, but the reds are more fiery, and the purples duller than when the same cloth is dyed with madder or alizarine.

It has been shown by Dr. Schunck that the mordants on cloth which has been dyed with madder, and then boiled in soap water, retain the alizarine, but not the purpurine, the action of the soap having removed the latter; hence it seems that alizarine is the essential colouring matter in madder dyeing.

Although it is certainly contained in ordinary madder roots, it appears from Dr. Schunck's experiments that the whole of the colour does not exist ready formed, but that the root has a colour-giving principle which he called rubian. This substance he extracted, and found that it was decomposed by acids and alkalies with the production of alizarine. The root itself was also found to contain a nitrogenous substance called erythrozym, which acts like a ferment upon rubian, causing its decomposition; hence Dr. Schunck considers it probable that the alizarine which exists ready formed in madder is due to the fermentation of rubian. Madder also contains several substances which act injuriously in dyeing, either by imparting a dirty reddish-brown tinge, both to the mordanted and unmordanted parts of the cloth, or by combining with the mordants and preventing them from taking up the true colouring matter.

Several preparations of madder are known in commerce under the names of flowers of madder, garancine, alizarine, and purpurine, in which the removal of these injurious substances has been more or less effected. These preparations are obtained by the action of water or strong acids upon the madder, or by high-pressure steam upon madder which has been treated with acid. Many of the injurious substances soluble in water are thus washed away or decomposed, and at the same time the action of the acid upon the rubian still existing in the madder increases the quantity of alizarine and purpurine, thus rendering nearly all the colouring matter available for dyeing. These preparations usually yield *brighter* colours and stain the unmordanted parts of the

cloth much less than madder; and therefore, as the colours require less clearing, they are much used for dyeing, in combination with various dye woods for producing compound and deep shades in low-class styles where the maximum degree of fastness and permanence is not required.

Within the last few years several extracts of madder have been introduced, consisting of alizarine, or purpurine in a remarkable state of purity, and mostly used for topical dyeing, i. e. mixed with the necessary mordant, thickened with starch paste, or gum water, and applied by impression. The colours are fixed by steaming, and then brightened by boiling with soap. These extracts are extremely useful to the calico printer, because they can be used in conjunction with pigments or other colouring matters thickened with albumen, as the steaming also fixes the latter by the coagulation of the albumen. We are thus enabled, by one operation of printing, to apply both madder colours and pigments, and produce effects which formerly required, 1st, the printing of the madder mordants, and dyeing, and 2nd, the introduction of steam colours by blocks, cut so as to apply them to their proper places upon the dyed cloth.

In 1869 two German chemists, Messrs. Græbe and Liebermann, announced that they had succeeded in the production of alizarine by artificial means, from anthracene, a white solid substance, one of the products of the dry distillation of coal. This most important discovery, the first case in which an organic colouring matter has been artificially prepared, has already received a practical application, for large quantities of

artificial alizarine are now made for the use of dyers and calico printers. The ultimate effect of this discovery upon the consumption of madder cannot yet be foreseen; but the small cost at which the artificial product is now manufactured, has brought down the price of madder to a point at which the question is raised:—How much longer can it be produced with profit to the grower? The artificial and natural alizarine are undoubtedly identical in composition, and the former is now used in preference to the latter by calico printers for many of their madder styles: it is also successfully applied in Turkey red dyeing, and in the preparation of steam colours for topical printing. The use of artificial alizarine in dyeing necessitates an alteration in the strength of the mordants, to produce shades equal in intensity to those produced with madder; the dyeing is also effected much more rapidly, and with less attention to the gradual rise of temperature, which is so important in madder dyeing, and the goods when removed from the bath require much less treatment with soap to brighten the colours, owing to the purity of the dye stuff.

Rosaniline in the pure state is a colourless base obtained by the action of many substances, e. g. stannic chloride, arsenic acid, &c., upon a mixture of aniline and toluidine. With acids it forms red-coloured salts; the chloride anda cetate are the most soluble, and are therefore the ones generally used; they are known under the names of fuchsine and roseine respectively, or the salts in general under that of magenta. These salts are used for dyeing silk, woollen, and cotton goods, the

two former attracting the colouring matter by simple immersion in hot water, to which the dye is gradually added in sufficient quantity to produce the required depth of colour. Cotton fibres have no attraction for this colouring matter, but it may be fixed upon calico which has been mordanted with alumina; or if a pattern be required, the fabric, whatever be the nature of the fibre, may be printed with a solution of the colouring matter thickened with albumen and then steamed, the albumen here playing the part of a mordant as well as that of a mechanical fixing agent.

The chief yellow colouring matters are the yellow chromate of lead, Persian berries, quercitron bark, fustic, weld, picric acid, and the aniline yellow or orange dyes.

Under Persian berries are included those of several species of *Rhamnus*. The yellow colouring matter of these berries is very soluble in water, and it is fixed upon cloth prepared with an aluminous or tin mordant, by dyeing in a bath containing the ground berries, or a decoction of the same. An extract of Persian berries is also used for preparing a steam yellow colour for printing, by mixing it with an aluminous or tin mordant, thickening with starch, printing upon cloth prepared with stannic oxide, and steaming.

Quercitron is the bark of a species of oak, imported from the United States. It contains a yellow colouring matter, which is used for dyeing woollen and cotton goods, the former with a tin, the latter with an aluminous mordant. The ground bark is also used in garancine dyeing for modifying the shades imparted by the garancine and other dye woods.

Fustic, commonly called old fustic, is the ground wood of a West Indian tree, called *Morus tinctoria*, and is chiefly used in woollen dyeing with an aluminous mordant.

Weld is the dried leaves and stems of the *Riseda luteola*, a plant which is probably a native of this country, and was formerly cultivated here for the use of dyers. A decoction is still used, though not so much as formerly, for dyeing cotton, silk, and woollen goods. With an aluminous mordant it yields a yellow colour, possessed of much brilliancy and permanence.

Picric or carbazotic acid is formed by the action of nitric acid upon many organic substances, e. g. indigo, carbolic acid, &c. It occurs in the form of pale-yellow crystalline plates, which are slightly soluble in water, but dissolve more easily in alcohol or ether. Picric acid possesses very great tinctorial power, but has no affinity for cotton. It dyes wool or silk a beautiful yellow without any mordant.

The so-called black colours are produced in such a variety of ways that it is impossible here to notice more than one or two processes. Black is frequently produced by the successive superposition of the colours derived from different dye stuffs, though a few black dyes may be obtained directly. The stuffs mostly used in black dyeing are madder, logwood, sumach, and gall nuts.

Logwood is the wood of the *Hæmatoxylon Campechianum*, a native tree of Central America. Cotton goods may be dyed black with it, by first mordanting them with ferric oxide or a mixture of ferric oxide and alumina, and then dyeing in a bath containing the ground wood;

the permanence of the black is much increased by the addition of sumach to the bath. Black upon woollen goods is generally obtained by first dyeing them blue in the indigo vat, or with sulhpate of indigo or Prussian blue, and again in a decoction of logwood and sumach, with the addition of ferrous sulphate.

Aniline black, perhaps the fastest of all known colours, is produced by the oxidation of aniline. It is applied to cotton goods, generally, by printing them with a mixture containing a soluble salt of aniline, usually the chloride; chlorate of potash or soda; and a salt of copper, preferably the sulphide. The black is gradually developed, after printing, by exposure of the cloth to the air, and the goods merely require to be passed through an alkaline solution and boiled in a solution of soap.

The use of astringents in dyeing depends upon the tannic acid which they contain, but their action is not clearly understood; it is found, however, that, in combination with the ordinary mordants, tannic acid aids the attraction of colouring matter to the fibre, and adds depth and brilliancy to the colours. The astringents most valued in dyeing are gall nuts and sumach.

Gall nuts are excrescences produced upon the epidermis of a species of oak, the result of punctures made by insects for the purpose of depositing their eggs.

Sumach is obtained by reducing to powder the dried leaves and twigs of various shrubs belonging to the genus *Rhus*.

Purple or violet colours are sometimes obtained by the mixture of blue and red dyes. Thus woollen

fabrics may be dyed purple by first dipping them in an indigo vat and then dyeing with cochineal and an aluminous mordant. Or the goods mordanted with alumina may be dyed successively with logwood and cochineal.

The special dye stuffs for the direct production of purple colours are madder, garancine, alizarine, archil, and the aniline purple dyes.

Madder and alizarine produce the most valuable and permanent purple colours upon cotton fabrics. An iron mordant is required for this purpose, and by varying its concentration, all shades from the palest purple to one so dark as to appear black may be obtained. The goods are well washed after dyeing, and then boiled in a weak soap solution to brighten the colours. Garancine also yields purple shades with the same mordant, but they are neither so fast nor so brilliant.

Archil is a colouring matter derived from various species of lichens, by steeping them in alkaline solutions. It is chiefly used in silk dyeing for the production of various shades of violet, no mordant being required. Archil colours, though very beautiful, are very fugitive, and on this account have been superseded to a great extent by the aniline dyes.

On account of the extraordinary brilliancy and variety of shade of aniline purples and their strong affinity for animal fibres, they have nearly superseded all other purple dyes for woollen and silk. The goods are dyed by simple immersion in a bath containing the colouring matter. Aniline purples are also used in dyeing cotton goods, but require the aid of a mordant, of which several have been proposed, e. g. the goods

may be mordanted with red liquor, dried, rinsed in water, and finally dyed in a bath containing a lukewarm solution of the colouring matter; or they may be mordanted with basic acetate of lead; or with stannic oxide or alumina, then impregnated with a solution of tannic acid or a decoction of sumach, and dyed as before. The aniline purples and other aniline dyes may also be applied, by topically mixing their solutions with albumen and printing the colour upon the cloth in the ordinary way. The albumen forms a kind of mordant for the colouring matter, and, when coagulated by steam, fixes it upon the fibre. Or the cloth, previously mordanted with stannic oxide, may be printed with a thickened solution of tannic acid and dyed in a solution of the colouring matter.

Green colours are generally obtained by the mixture of blue and yellow dyes. Thus, according to circumstances and the nature of the fibre, the goods may be first dyed blue in the indigo vat, or with sulphate of indigo, Prussian blue, or logwood, and then yellow by a second dyeing with fustic, bark, or Persian berries, with an aluminous or tin mordant, or with picric acid. The special green dyes are arseniate of copper, chrome green, and aniline green.

Arsenite of copper, or Scheele's green, is applied to cotton goods by printing them with a copper salt, fixing the cupric hydrate within the fibre by passing them through milk of lime, and then converting the cupric hydrate into arsenite of copper by a passage through a solution of arsenious acid or arsenite of soda.

Chrome greens consist of chromic hydrate, and are

either formed within the fibre by precipitation, or are applied as pigments mixed with albumen.

Aniline green may be fixed upon cotton by preparing the goods with tannic acid or a decoction of sumach along with a tin or aluminous mordant, then immersing in a bath containing the colouring matter. Wool and silk attract the dye without the aid of any mordant.

Chocolate colours upon cotton are obtained by mordanting with a mixture of alumina and ferric oxide, and dyeing with madder or garancine, or by printing a mixture containing extracts of logwood, bark, and sapan with alum or acetate of alumina, and then steaming. In dyeing chocolates with garancine, it is usual to add to the dye bath a certain quantity of bark, sumach, and sapan, chiefly for the sake of economy. Upon wool, chocolates are obtained by the use of different dye stuffs, e. g. fustic, peachwood, logwood, &c., with an aluminous mordant.

Brown, like chocolate, may be obtained by the mixture of various dye stuffs, but it is generally obtained on cotton goods, by means of catechu.

Catechu is an extract from different parts of certain trees, chiefly natives of India, viz. the *Areca catechu*, *Acacia catechu*, and *Uncaria gambir*. It contains an astringent principle, or a kind of tannin, and a substance called catechine. It is applied by dissolving in water, with the addition of acetic acid, sal-ammoniac, gum water, and a salt of copper, this mixture being then printed upon the cloth. The copper salt effects the oxidation of the catechine, and its conversion into an insoluble brown substance. The oxidation takes

place when the printed goods are exposed to the air, and as the colour when properly fixed will resist the operations of dunging and dyeing, it is frequently used in conjunction with the ordinary aluminous or iron mordants, for dyeing with madder or garancine.

Buff and orange are obtained by the mixture in various proportions of red and yellow dye stuffs, fixed by means of their proper mordants, or from annotto, or by methods already described.

Annotto is a pasty substance prepared from the seeds of the *Bixa orellana*, a native shrub of Central America. It contains an orange colouring matter called bixin. It is chiefly used for dyeing silk mordanted with alum, by immersion in a cold alkaline solution of the colouring matter, until the desired shade is obtained.

In the production of coloured patterns upon cloth, the designs are seldom complete without the introduction of white. In calico printing, those parts of the cloth to which no colouring matter, or mordant for the attraction of colouring matter, has been applied, regain their original whiteness after the clearing, or treatment with hot water, soap solution, or dilute bleaching liquor, which in these cases always follows the washing of the goods when removed from the dye bath. But when the colouring matters or mordants have been applied to the entire surface of the fabric, for the purpose of obtaining coloured grounds, white is obtained in the pattern or design upon these coloured grounds by resisting the fixation of the mordants or colouring matter, or by discharging the colour in places, if the fabric has been already dyed. The chief resists are citric acid

or lemon juice for iron and aluminous mordants; their action consists in retaining the mordants printed over them, in a soluble condition, until their removal from the cloth in the process of dunging. For indigo blue dipping, mixtures of pipeclay, soap, sulphate of copper, or zinc, thickened with gum, are used as resists; their action is partly mechanical, for they prevent the entrance of the indigo solution into the fibre, and partly chemical, for they cause the oxidation or precipitation of the indigo white before it can be absorbed by the fibre. A white object is discharged upon a coloured ground by the impression upon the dyed cloth of various chemical agents, which will effect the destruction of the colouring matter.

BLEACHING.

By T. Sims (Mayfield Print Works).

Textile materials, in their raw or natural condition, always contain certain colouring substances. The term "bleaching" is applied to those processes by which these substances are removed or destroyed, so that the fibre is obtained in a state of purity. In the case of fabrics intended to be dyed, the only object of the bleacher is to deprive them, as nearly as possible, of all colouring matters, and to give them that snowy whiteness which is so pleasing to the eye; but if the bleaching of the goods has to be followed by dyeing, it is further necessary to remove all foreign substances introduced either accidentally or intentionally during their manufacture, and which, if left attached to the fibre, would interfere with the production of bright and delicate colours.

The art of bleaching has been practised from the remotest ages. The oldest known method, though exceedingly tedious and laborious, is still carried on in some places for hempen and flaxen goods, and consists in spreading out the tissues upon a meadow, so that they are fully exposed to the combined action of sunlight, air, and moisture for several days; after which they are washed in a weak alkaline solution.

Successive exposures, followed by treatment with weak alkalines, are required before the goods are perfectly bleached. The original discovery of this method of bleaching was probably the result of mere accident; for exposure to the air and sunlight, for drying goods that had been washed, would be necessarily followed by a more or less perfect whitening of the tissues. The detergent action of various substances, of mineral, vegetable, or even of animal origin, seems to have been known to the ancients, and applied by them to bleaching purposes. Lime, potash, soda, and ammoniacal liquors; the infusions of various plants, especially of the *Saponaria officinalis*, or soapwort, and *Arum maculatum*, or cuckoo-pint, and also the husks of wheat, &c., have long been used in different countries; it is therefore probable that the earliest modes of bleaching depended upon the use of such bodies, aided by the action of the air and sunlight. The bleaching of woollen goods by sulphur vapours was also practised in early times by suspending the goods in a tent in which sulphur was burnt. In the last century, and before the introduction of American cotton, linen fabrics were generally used, and the manufacturers, even in this country, used to send their goods to be bleached in Holland; the Dutch at that time being celebrated for their bleaching. Their process consisted in steeping the goods in an alkaline ley, and pouring upon them a boiling solution of potash; and after remaining in this solution for some days, the cloth was washed, placed in cisterns along with butter-milk,

then trodden by the feet, and afterwards subjected to pressure. After several days the cloth was removed from the cisterns and washed, first with soap, and then with water. These operations were repeated several times if necessary, and finally it was spread upon the ground to bleach. The entire process occupied eight or ten weeks. Dr. Home, of Edinburgh, discovered that the action of the butter-milk was due to its acidity, and proposed the use of a weak solution of sulphuric acid in place of it, which proved a decided improvement and a great saving of time. In 1774 the Swedish chemist Scheele made the important discovery of chlorine, which, according to the chemical views of that day, he called dephlogisticated muriatic acid. In 1785, Berthollet investigated this substance, and showed that it should rather be called oxygenated muriatic acid, its elementary nature not being clearly established until the year 1810, when Sir H. Davy gave it the name of chlorine. It was Berthollet, however, who first drew attention to the property which chlorine possesses of destroying colouring matters, and he suggested a mode of bleaching, in which an aqueous solution was used as the decolouring agent. But either from prejudice or from insufficient chemical knowledge, it was some time before the use of chlorine became general. The rapid increase in the manufacture of cotton goods, however, led at last to the adoption of the chlorine process at Glasgow and Manchester, under the direction of Mr. James Watt and Dr. Henry. Owing to the noxious character of chlorine

gas, and the rather too energetic action which it had upon the fabrics, Berthollet proposed the use of a solution of chlorine in potash instead of in water. In 1798, Mr. Charles Tennant, of Glasgow, took out a patent for making a solution of the so-called chloride of lime; and by afterwards impregnating quicklime with chlorine, he obtained the solid substance still known and most extensively used under the name of bleaching powder.

The best qualities of cotton consist of nearly pure cellulose, and are therefore nearly devoid of colour; but the inferior qualities are always more or less coloured with resinous and other matters derived from the plant. Cotton is bleached sometimes in the state of yarn, but more generally after it has been woven into cloth.

Grey or unbleached calico contains the following impurities:

1. Accidentally introduced during the gathering, packing, &c., such as earthy matters, dust, animal exudations, seed vessels, &c.
2. Certain resinous substances and colouring matters, which always accompany the fibre in its natural state.
3. Fatty matters and metallic particles introduced during the processes of spinning and weaving; also various metallic soaps formed by the combination of these substances.
4. Weavers' paste, including flour, starch, size; calcareous and aluminous substances, intentionally added during the manufacturing operations.

Owing to the different nature of these impurities, it is impossible to remove them all by one single operation, and consequently the process of bleaching consists

of a series of operations, which will be described in the following order:

1. Singeing.
2. Steeping and Washing.
3. Bowking with Lime, and Washing.
4. Souring and Washing.
5. Bowking with Soda Ash, and Washing.
6. Chlorinating, commonly called Chemicking.
7. Souring, Washing, and Drying.

1. *Singeing* consists in burning off the loose fibres or nap. For this purpose a considerable number of pieces are sewed together, end to end, and rapidly drawn over a red-hot semicircular copper plate placed horizontally over the flue of a fireplace. By another method, the goods are passed over the flame from a series of gas-jets, placed in a row upon the upper surface of a horizontal pipe connected with the gas mains. A third apparatus consists of a coke furnace, the flame of which is forced, by means of a fan, from a long narrow slit at the top. The cloth is drawn by power first over this flame, then over a red-hot plate, and finally through a steam-box, where any sparks are at once extinguished.

2. *Steeping.*—In some bleach-works it is the custom to allow the goods to steep for some hours in water, and then to wash them, in order to soften or partially remove the pasty materials, and so to put the cloth in a condition to absorb the bleaching solutions with ease and rapidity. It has been proposed to effect this more thoroughly by steeping the cloth in water at a temperature of about 140° Fahr., to which a certain quantity of

malt has been added. The diastase in the malt acts upon the starchy matters, converting them into dextrine or sugar, which, being soluble, is removed by the washing. This latter method is seldom resorted to; and to save time, the steeping process is often omitted entirely, the goods being merely washed before they are subjected to the next operation.

All the modern improvements in the various operations of bleaching have for their ultimate object the economy of time and manual labour, and, as a natural consequence, increased production at less cost. The chief mode by which these requirements are gained is, by rendering the successive processes as continuous as possible, machine power being applied wherever available. Formerly the pieces were operated upon detached from one another, but now they are drawn by rollers and winches from one operation to another in an unbroken chain, their course being guided by passing the chain through earthenware loops, called "pot eyes." The introduction of sewing machines, by which the ends of the pieces are fastened together, has lent considerable aid to the carrying out of this continuous process.

This plan has caused the disuse to a very large extent of the older methods of washing. The dash-wheel is still occasionally used, and is an excellent machine, though slow and costly. It consists of a hollow cylindrical box of wood, 5 or 6 feet in diameter, and about 2 feet in depth, divided into four compartments, each of which has a circular opening at the front of the wheel. One or two pieces of the cloth are

introduced into each compartment through the openings, and the wheel is set revolving upon its axis; at the same time water is admitted through an opening at the back. The concussions which the cloth receives at every revolution of the wheel so agitate it with the water, that the washing is very effectively performed. The dirty water escapes through a series of holes round the circumference of the back of the wheel.

Various machines have been constructed, by which the washing can be performed in much less time than by the dash-wheel, and without the necessity of detaching the pieces from one another. The annexed figures, from drawings supplied by Messrs. Furnevall and Co., of Haslingden, represent the form of washing machine commonly used in bleach-works. It consists of two long squeezing or drawing rollers A B, supported in contact with each other by a suitable framework over the cistern C containing the water. The pieces, sewed together end to end, enter this machine at both sides through earthenware loops D E, which guide them in a rope-like form between the two squeezing rollers; they then fall down on the other side into the liquor in the cistern or trough below; and after passing under another roller F, submerged in the liquor, are conducted again between the pressure rollers, and thus pass onwards, ascending and descending in a spiral form, until they reach the centre of the machine, where they leave it, after receiving a final squeeze between the two pressure rollers. The gearing, by which the machine is driven, is attached to the axle of the lower of the two squeezing rollers; the upper roller moves by

friction against the other, the pressure being regulated by screws with levers and weights attached to the

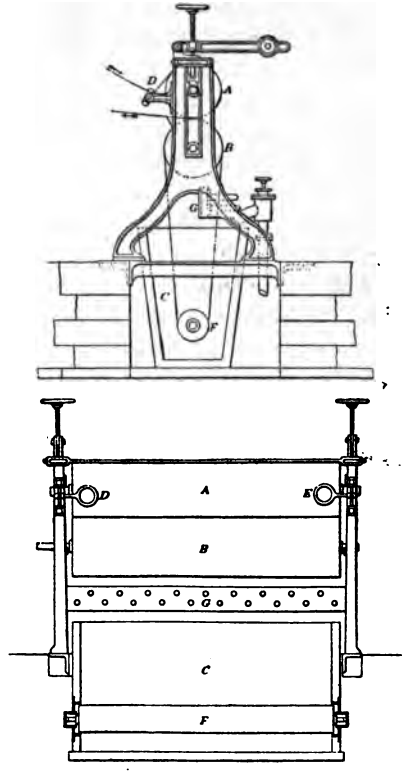


Fig. 1.—Side and Front Elevations of Washing Machine.

bearings. The pieces in their course through the machine pass between the projecting pegs of a rail G,

which is fixed to the framework at either side, and are thus prevented from becoming entangled.

3. *Bowking or Bucking with lime* consists in boiling the goods with milk of lime in large cylindrical vessels called "kiers." The object of the bleacher being to expose the cloth for some hours at a temperature of at least 212° Fahr. to the action of a weak alkaline solution, it was necessary to have a vessel constructed in such a manner that during the operation of boiling it should be thoroughly impregnated with the solution. Various forms of apparatus have been constructed for this purpose. The oldest kier consisted of a vessel or receptacle, placed above a boiler containing the alkaline ley heated to ebullition by means of a fire. The inconveniences arising from the great heat required to force the liquor through the cloth led to the use of a pump, by which the liquor was raised and poured again upon the goods. The first considerable improvement in this kier seems to have been made by Mr. Widmer, who dispensed with the pump, and caused the ley to rise by means of the pressure of its own vapour. His kier consisted, in the first place, of an iron pan A (Fig. 2), set in brickwork, and heated in the ordinary way by a fire underneath. Immediately above, and resting on the brickwork, was a large cylindrical vessel B, made either of iron or wood, and having a perforated bottom C, which thus divided the kier into an upper and lower compartment. The former was the receptacle for the goods, and the latter for the ley. The perforated division between the two parts served as a support for the cloth, and kept it from direct contact with the

heated portions of the pan. A vertical iron pipe D was fixed in the centre of the perforated bottom of the upper cylinder; the upper portion of this pipe rose

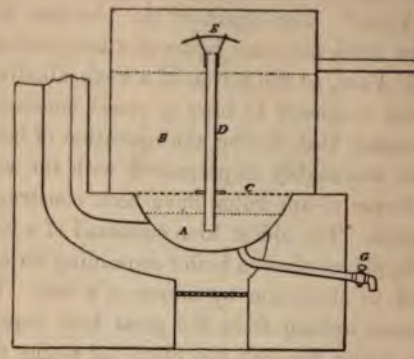


Fig. 2.

nearly to the top of the kier, and the lower part dipped into the liquor contained in the pan. The kier was charged by placing the goods in regular layers round the vertical pipe. The circulation of the boiling ley through the goods was effected by means of the vertical pipe. It commenced when the liquor in the pan began to boil, for the vapour from the boiling ley being unable to pass through the layers of cloth, soon acquired sufficient tension to force a portion of the liquor up the pipe. A concave cap or cover E, placed at a little above the upper mouth of the pipe, reflected the boiling ley, as it rose from the pipe, upon the goods. It then percolated through the folds of cloth, and descended through the perforations in the false bottom

into the pan below, where it was again heated and forced upwards, as before. Attached to the bottom of the pan was an iron pipe G, with a stop-cock, by means of which the liquor could be drawn off at the end of the operation.

An improved form of kier is much used at the present time. It consists of one single steam-tight

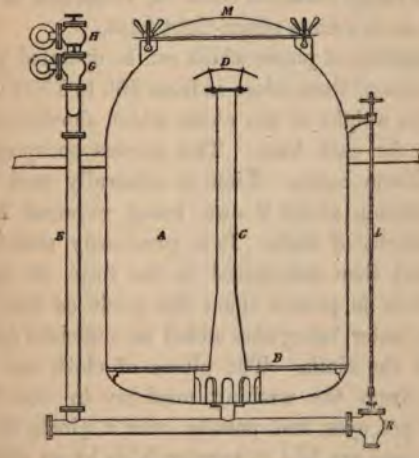


Fig. 3.—Section of Low-pressure Kier.

vessel (A, Fig. 3), of a cylindrical shape, generally of cast iron, and heated by low-pressure steam instead of by fire. The goods rest upon a false bottom or grating B, and a vertical pipe C, with a cap or spreader D at its upper opening, causes the circulation of the liquid and its distribution over the cloth. An iron pipe E, communicating with the kier below

the false bottom, has two branches, each of which is provided with a valve, the one, G, supplying steam, and the other, H, water to the kier. The same pipe E serves also for letting off the liquor in the kier, the valve K for this purpose at the bottom of the kier being opened or shut by means of the wheel and connecting rod I. The mouth of the kier is flanged, and upon the flange rests the cover M, which can be bolted down so as to form a steam-tight joint.

The number of pieces which can be operated upon at once in one of these kiers is from 600 to 1500 according to the weight of the cloth, which should be about 3500 lb. for each kier. The process occupies from ten to fifteen hours. Lime is generally used in the first bowking, about 2 cwt. being required for the above weight of cloth. It is previously slaked with water, and then introduced in the form of milk of lime, which is poured upon the goods as they enter the kier, water being also added in sufficient quantity to cover the cloth. The pieces of cloth are drawn straight from the washing machine in one length through pot eyes, and, passing over a winch, fall into the kier, and are laid in regular folds by an attendant boy.

Another system of bowking, called the high pressure, requires the use of kiers which can be heated by high-pressure steam. In Mr. Barlow's method, a pair of similar kiers are placed side by side, and are worked together. They consist of two large cylinders of equal size (A B, Fig. 4), made of strong boiler-plate iron, and are connected by two different pipes, the one, C,

joining the top of the first kier with the bottom of the second, and the other, D, joining the top of the second with the bottom of the first. Each pipe is furnished

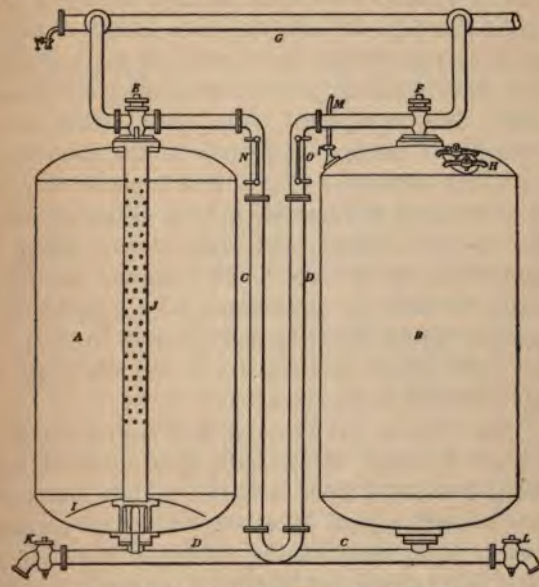


Fig. 4.—Barlow's High-pressure Bowking Kier.

with a valve or two-way tap E F, by which the communication between the kiers can be opened or closed, and which also connects the kiers with the main steam-pipe G. The pieces of cloth sewed together in one length are first passed through milk of lime, and then introduced into one of the kiers through its man-hole H, and placed in regular layers upon a plate of iron

I, fixed at the bottom of the kier: this plate is perforated with holes round its outer edge for the passage of the liquor. A vertical pipe J, called "the distributor," is also fixed within the kier; the upper portion of this pipe is perforated with numerous holes, and is connected with the "inlet" of the kier; the lower portion has no perforations, and is completely closed. The arrangement is the same in both kiers, and both are charged with cloth at the same time. When they are filled, a ring or grid is placed over the top of the goods to keep them in their place; the manholes are then closed, and high-pressure steam is admitted through the taps E and F, so that the steam passing through the perforations of the distributor impinges against the cloth, and forces downwards the lime water, which is drawn off by the stop-cocks K and L, attached to the pipes C and D.

When nothing but steam escapes from these stop-cocks, it is turned off, and milk of lime diluted with a large quantity of water is introduced into one of the kiers through a pipe, M, at the top. High-pressure steam is again admitted, the exit pipes, K and L, of course being closed, and this forces the liquor through the goods to the bottom of the kier, and up the connecting pipe D or C, through the valve F or E, and into the distributor of the adjoining kier. The liquor then passes through the perforations, and is distributed amongst the folds of the cloth. When all has thus been forced from one kier into the other, which is ascertained by means of the gauge pipes N or O, the steam is shut off the first kier, and turned on to the

second, the liquor being then forced through the goods in this kier, and up the connecting pipe C or D, back again into the first. This alternate forcing of the liquor from one kier into the other is continued for about eight hours, after which the pieces are withdrawn by passing them over a winch and through pot eyes, which conduct them to the washing machine.

This mode of bleaching by high-pressure steam possesses several advantages over low pressure: 1st, economy of time, resulting from the more energetic and rapid action of the alkaline solutions at the elevated temperature at which the operations are performed; 2nd, the more complete impregnation of the goods with the liquor. But, on the other hand, it has its disadvantages. For one thing, the use of high-pressure steam is not unattended with danger to the workmen employed about the kiers; several fatal accidents from their bursting have been recorded, though it is fair to add that these have generally occurred through some defect in construction; 2nd, the apparatus requires constant attention, and to ensure success, the management of the kiers should only be entrusted to competent workmen.

4. *Souring and Washing* consist in passing the goods through a weak solution of hydrochloric acid, and then through water. The object of this process is to decompose the insoluble lime soap formed during the preceding operation, and to remove the lime; also to dissolve out any metallic oxides that may be attached to the fibre. The process is conducted in the washing machine already described, the cistern being filled, and supplied with the acid liquor instead of water. After

souring, the goods are allowed to lie for a few hours, in order that the acid may have time to act, and then after washing they are passed on to the next process.

5. *Bowking with Soda Ash.*—This operation is performed in kiers, as already described. The soda ash along with a certain quantity of rosin soap is placed at the bottom of the kier, where it is soon dissolved by the water; or the solution is prepared in a separate cistern and run into the kier through a pipe. About $1\frac{1}{2}$ cwt. of soda ash and 80 lb. of rosin soap are required for 3500 lb. of cloth. By boiling with soda ash, the fatty acids which the cloth has hitherto retained are converted into soluble soda soaps, and are easily removed by the washing which the cloth receives, after it is withdrawn from the kiers.

6. *Chlorinating, or Chemicking.*—The cloth having passed through the operations already described has been deprived of nearly all its impurities, but is still wanting in perfect whiteness. To destroy the last traces of colouring matter, the pieces are passed through a very dilute solution of bleaching powder, at spec. grav. 1·0025 or $\frac{1}{2}°$ Twaddle, till thoroughly impregnated with the liquor, and then through squeezing rollers, to remove the excess of the solution; after which they are allowed to lie for some hours.

The action of the liquor is due to the decomposition of the chemical compounds which it contains. Bleaching powder may be considered as a mixture of hypochlorite and chloride of calcium. The former salt is easily decomposed by the action of weak acids, with the evolution of hypochlorous acid, which itself has

bleaching properties. This decomposition is partly effected by the carbonic acid in the air; but the action is rendered more rapid and complete by passing the goods, whilst still retaining the bleaching liquor, through a dilute acid solution. In this operation the liberated hypochlorous acid is itself decomposed and chlorine set free.

7. *Souring.*—This second passage of the goods through weak acid is performed as before. Sulphuric acid of a spec. grav. of 1·075 or 1½° Twaddle is generally used.

The final operations, to which the cloth is now subjected, are washing and drying, the last being performed by passing the pieces, opened out to their full extent, over and under a series of hollow tinned iron or copper cylinders, which are heated by steam; the greater portion of the water is, however, previously removed by passing the cloth between a pair of squeezing rollers.

Cotton is also bleached in the state of yarn. The skeins are first boiled in water, and then in a weak soda ley; and after washing, they are immersed in a solution of bleaching powder, then in weak acid, and finally washed again and dried.

Theory of Bleaching.—The art of bleaching consists in subjecting the fibrous material to various operations in succession; of these, the washing, bowking with lime and soda, and the intermediate souring, are, strictly speaking, detergent or cleansing processes; and, essential as they are to effect the removal from the cloth of the resinous, fatty, and mineral impurities which are attached to the fibre, still they must be considered as

merely preparatory or preliminary operations to the actual bleaching, which in former times was performed by exposure to the air, sunlight, and moisture, but is now effected by the agency of chlorine.

It is well known that oxygen has the power of destroying organic colouring matters, especially in its nascent state, or when it exists in the peculiar allotropic condition called ozone. Ozone is frequently present in the atmosphere, and therefore the bleaching of fabrics by exposure to the air may be due to its influence. Chlorine acts indirectly as an oxidizing agent; hence it is generally admitted that the phenomena of bleaching are the effects of oxidation. Chlorine possesses a marked affinity for hydrogen; and has also the power of replacing hydrogen by substitution. In the presence of water, (and this is always the case in bleaching operations, which alone I am now describing), the decolorization may be explained by supposing that the chlorine abstracts the hydrogen from the water, and sets free the oxygen, which unites with the colouring substance, producing a colourless compound.

The fibre of flax and hemp requires a preparation before it can be submitted to the process of manufacture, which is quite unnecessary in the case of cotton. This preparation is called retting, and it consists in macerating the stems of the plant in water, in order to destroy by fermentation the mucilaginous substances which hold together the fibrous portions of the bark, and to separate the fibres from the woody matter. During this fermentation a colouring substance is *formed* which attaches itself to the fibres. It is inso-

luble in boiling water, acids, and alkalies, but becomes soluble in alkalies after exposure to the air, sunlight, and moisture, or to the influence of chlorine. The bleaching of linen cloth is therefore effected by a series of alternate exposures to the air, by spreading the cloth upon the grass, or to the action of chlorine and alkaline solutions. The amount of colouring matter in linen is much greater than in cotton, consequently the former loses much more weight in bleaching than the latter. The loss in cotton goods is about 5 per cent., but in linen it amounts to as much as 33 per cent. The bleaching of linen goods is still a very tedious process. The method much resembles that employed for cotton fabrics, but the various operations require to be repeated more frequently.

Woollen fibre, in its natural condition, is covered with a soapy coat or film, called the yolk. This substance consists chiefly of fatty matters combined with potash; it is, for the most part, soluble in water, and hence the first operation consists in washing the wool with water. The well-known process of sheep washing, which precedes the shearing, removes not only the dirt which adheres to the wool whilst on the animal, but also a great part of the yolk. The wool, after shearing, still contains a considerable quantity of fatty substances; these are rendered soluble by steeping and gently agitating it for some minutes in a warm and slightly alkaline bath composed of soap and water, or a solution of carbonate of soda, or more frequently of stale urine diluted with four or five times its volume of warm water. Woollen fibres have a peculiar property

of adhering together, called felting, when they are violently agitated; it is necessary, therefore, to avoid this during scouring. The temperature must also be attended to, for woollen goods are liable to contraction, and also to a partial destruction of their fibre when too much heat is allowed in these operations.

Though wool is bleached in the fleece, it is more often in the state of yarn or cloth; but the scouring process is similar in all cases.

The actual bleaching is effected by sulphurous acid after the scouring is complete. The goods may be either steeped in, or passed through an aqueous solution of the gas, or they may be hung up in chambers in which sulphur is burnt, or they may be drawn through a chamber, furnished with rollers at the top and bottom to carry the cloth, into which sulphurous acid from burning sulphur is passed.

This acid was known as a decolorizing agent long before the discovery of chlorine, and it is still used in bleaching animal fibres, as chlorine and hypochlorous acid exert an injurious action upon them. It possesses powerful deoxidizing or reducing properties, readily absorbs oxygen, and is converted into sulphuric acid. Its action in bleaching may therefore be due to the deoxidation of the colouring matters, though in some cases it appears that sulphurous acid unites directly with the colouring matter and produces colourless compounds, for the original colour is often restored on the addition of a stronger acid to expel the sulphurous acid, or by neutralizing the latter by an *alkali.*

Silk in its original state is a peculiar secretion from the silkworm. It issues in the form of extremely fine threads, which harden by exposure to the air. In its raw state it resembles wool, insomuch that the fibres are coated with a kind of varnish, but this coating is of a waxy rather than of a fatty nature, and contains gelatinous, albuminous, fatty, and resinous substances, as well as colouring matter, all of which are removable by heating the silk nearly to ebullition in a strong solution of soap, and then washing. The last traces of colouring matter are removed, by exposing the silk to the action of sulphurous acid in the sulphuring chamber.

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